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THE SPECTRUM OF THE BESSEMER FLAME.

(DR. H. WEDDING.—Preus. Ztschft., Bd. XVII., 2to Ziof.)

Translated By E. F. EURICH.

In the puddling furnace, the chemical reactions necessary to produce iron require several hours, whereas in the Bessemer process they only occupy from 20 to 40 minutes. From this it follows that a small difference in the duration of the process would change the character of the Bessemer metal more than that of the iron obtained by puddling. In the former process it is, moreover, much more difficult than in the latter to determine exactly when the metal has reached the desired composition, *i. e.*, contains only a certain amount of carbon. On this account, the more rational and cheaper method of producing Bessemer metal directly has been mostly abandoned, it being considered preferable to decarbonize the pig-iron completely, and then to bring it back to the state of steel by the addition of a certain amount of pig-iron, rich in carbon (generally spiegeleisen).

On account of the difficulty in directly observing with the naked eye the reactions of the metal during the Bessemer process, other indications for judging of the state of the reaction had to be sought. Samples taken with a ladle, or by means of an iron bar, give a good insight into the character of the product, and on this account are employed in some places (Styria, Westphalia). On the one hand, however, they are apt to exercise a disturbing influence on the process, and on the other, too much time is required before the operator is able to arrive at a satisfactory conclusion. Since, in consequence of influence beyond control, the duration of the period of reaction is scarcely ever exactly the same in any two operations, the determination of the time required for one operation would be of little benefit for determining the time required for other operations. We are therefore confined to observing the stream of gas issuing from the mouth of the converter, and of the solid particles contained in it, and torn along by it. Fortunately, the color and brightness of the stream of gas furnishes an indication for easily determining the period of total decarbonization, especially if only steel is to be made. When, however, the quality of the pig-iron to be worked varies, or certain qualities of steel are to be produced, whose carbon can only vary within narrow limits, a great deal of practice is necessary for conducting the process by the appearance of the flame, and even then mistakes occur quite frequently. Even under the direction of a skilful engineer, and with qualities of pig-iron whose behavior is known, variations in the quality of the product are not to be avoided. Though these variations do little harm in most cases—for instance, in the manufacture of

the lower qualities of steel for rails, or when the establishment has orders for articles requiring different grades of steel —yet the capability of the general application of the Bessemer process would be greatly increased, if signs clear, unerring, and independent of personal experience, could be discovered to mark the end of the reaction.

Since the flame in itself furnishes us characteristic indications, we may reasonably expect to attain our object by artificially intensifying these indications.

We have already remarked that the guide for determining the point for interrupting the process in order to add pig-iron, is the brightness and color of the flame. It was this last which, in consideration of the chemical reactions taking place in the converter, first drew attention to the application of the spectroscope to the Bessemer process.

Application of Spectral Analysis.—Wm. Bragg, of Sheffield, first suggested the use of spectral analysis for this purpose, and in consequence Prof. Roscoe was, in 1862, induced to make experiments at Brown's Works in Sheffield. In 1863 Roscoe published his first observations of the Bessemer flame. According to these the spectrum of the flame was sufficiently characteristic, and marked the various stages of the process with enough distinctness to give promise of its practical application. In the following year he announced to the Royal Institution that the spectroscope had been practically introduced into Brown's Works in Sheffield for correctly determining the point of decarbonization. Shortly after this time, the spectroscope is reported to have been used at Crewe, and from there it is said to have been taken to Seraing, in Belgium, in 1865.

When operations were commenced with the Bessemer process at the "Königshütte," in Upper Silesia, in 1865, experiments were at once begun with the spectroscope. The instrument was manufactured by a celebrated Berlin firm, yet the experiments were a complete failure. Only a continuous spectrum was obtained, and even the inevitable sodium line only appeared once in a while. Since the instrument was not considered unfit for the work, and since an experiment with carbonic oxide gas (to whose agency the lines in the spectrum were ascribed) gave no better results, the failure was ascribed to the operation itself.

In Austria, Prof. Zielegg followed up this subject with the greatest perseverance. His articles in the reports of the Imperial Academy of Sciences, give exact and trustworthy accounts of the varying character of the Bessemer spectrum during the different stages of the process. His examinations were made at Gratz, where the spectroscope was soon after used uninterruptedly with great success in controlling the Bessemer process. From there the spectroscope was taken to Ternitz, in Lower Austria, and to the "Maximilianshütte," in Bavaria. But at the same time the favorable results obtained at these works were not at all confirmed by experiments tried in other establishments, as at Neuberg, or received only a partial confirmation, as at Hörde.

Immediately after the publication of Prof. Zielegg's articles on the subject, experiments were renewed at the "Königshütte." In the mean time doubts had arisen as to the adaptation of the spectroscope first used, and a new one was obtained from the same firm which had furnished the one at Gratz—Messrs. Kammerer & Starke, in Vienna. This new series of experiments at the "Königshütte" gave results which seem to have met with general confirmation. It was found that the spectroscope could only be satisfactorily employed when the decarbonization was carried on to the point known in practice as that of total decarbonization, and with so-called "cold charges," *i. e.*, with charges pretty free of smoke. In the latter case the end of the reaction can be determined with great accuracy, even by an inexperienced person. For interrupting the decarbonization sooner, there is a lack of reliable indications. If the charges are hot, *i. e.*, have a great deal of smoke, the indications in the spectroscope which are to guide the operator are uncertain, and frequently are entirely wanting. In this case the lines whose disappearance is to indicate the correct point of time for ending the process, disappear too soon.

Explanation of the Spectrum.—Ever since Roscoe's examinations, a scientific explanation of the characteristic appearances of the spectrum of the Bessemer flame has been sought. It was thought to admit of little doubt that carbon, or some combi-

nation of carbon (carbonic oxide), played an important part in it. Comparative, but fruitless experiments were first made by Watt. Zielegg then followed with his thorough investigations. Both sought an explanation for the deviation of the Bessemer spectrum from the spectrum due to carbon, with which they compared it—not in the circumstance that the former was no carbon spectrum, but in the different conditions of its formation.

Brunnerfeist first called attention to the doubtfulness of this conclusion, and pointed out that the spectrum might be mainly due to manganese and iron, and not to carbon. From this a contest arose (not always remaining within the bounds of scientific research), which was carried on in the "Oest. Ztschft für Bguird Hist. Weser," and did a great deal towards clearing up matters. This subject was followed up at the "Königshütte," by Hasenöhel, and at the laboratory of the Mining Academy (Berlin), by Dr. Wiechmann and the author, and the experiments led to the confirmation of Brunner's views. These last were furthermore directly proven by a comparison of the manganese and Bessemer spectra in the same spectral apparatus, by Av. Lichtenfels, at Neuberg.

Thus this interesting subject has in one sense been brought to a close, and this will justify a critical examination of the work accomplished, for the purpose of gaining a secure foundation for future investigation. From henceforth investigation will have a different direction, but at the same time it promises results not the less interesting from the scientific or important from the technological point of view.

CONCLUSIONS AS TO THE SPECTRUM OF THE BESSEMER FLAME.

The character of the Bessemer flame, as it presents itself to the naked eye, in connection with the chemical reactions which take place in the converter during the process, permits us to draw certain preliminary conclusions as to the spectrum seen in the spectroscope.

Exterior Appearance of the Bessemer Flame.—At the commencement of the process no real flame appears, but only an illumined stream of gas containing numerous reddish sparks, which are mostly little pellets of iron. After a few minutes an orange-colored flame, of low luminous power and transparent, is formed; a few blue stripes appear in it and a whitish border is now and then seen on its edge. Gradually sparks of burnt iron and fragments of white hot slag are mixed with it; its brilliancy is increased, and the stream of gas, at first steady, becomes irregular and fitful. In the second period the flame is very bright, almost white; is very luminous, and contains numerous sparks of iron and pellets of slag which are sometimes ejected in a sheaf-like shape. A violent, restless flickering of the stream of gas only decreases at the end of the period, while the flame is brightest. With the commencement of the third period the eruptions become less frequent, without a diminution in the luminous power of the flame. After a few minutes, however, this becomes weaker, and the flame appears more transparent and contains blue and violet colors palpably intermixed. Only in the working of certain qualities of pig-iron (dark gray manganiferous iron) does the flame remain strongly luminous till the end of the charge (for instance, at Hörde). At the close of this period the flame suddenly ceases, and a transparent stream of gas, illuminated from within, is steadily expelled out of the mouth of the converter. At this point the process is interrupted. In the second period, and with some qualities of iron (especially if taken directly from the blast furnace), even in the first, the flame is mixed in a greater or less degree with a brown smoke, more seldom with a whitish or yellowish smoke. In the last period this smoke quite frequently appears in such quantities (as, for instance, at Königshütte) that even the existence of a flame can be scarcely observed. In this case it is of course very difficult to determine the time of the disappearance of the flame.

With the addition of the spiegeleisen, for the purpose of bringing the decarbonized iron back to steel, and if the blast at the same time be shut off, we notice an orange-yellow sooty flame, which, on again admitting the blast, changes into a flame resembling in color and appearance that at the commencement.

Chemical Reactions.—In the first period (the period of slag formation, or the firing period), the greatest part of the silicon contained in the pig-iron is oxidized by the oxygen of the blast, and in con-

junction with protoxide of iron and protoxide of manganese forms a slag, into which also enter silica, alumina, lime, magnesia, and alkali, from the lining of the converter. In the second period (the boiling or eruption period), the slag which has become a proto-silicate, takes up FeO, Fe_2O_3, and this acts decarbonizing on the pig-iron, with the formation of carbonic oxide, and probably also of carbonic acid. The calculated quality of oxygen in the blast seems at least to point to this last. The decarbonization of the iron is continued in the last period, until the desired degree of decarbonization has been reached, when the process is stopped. On the addition of spiegeleisen, which now takes place, there is partly only a mixture of the last with the decarbonized iron, and partly a chemical reaction takes place between the oxygen contained chemically, or mechanically, in the latter, and the carbon, silicon, manganese, etc., contained in the former. The whole process can therefore be traced back to an oxidation. Of the products of this oxidation, the carbon combinations (carbonic oxide and carbonic acid) are always gases, while the oxides of silicon, iron, and manganese, can only, on account of the high temperature, appear in part in the form of vapor. That these last really appear in this shape is proven by the analysis of the brown smoke, giving silica, protoxide of manganese, and protoxide of iron.

Of the other bodies contained in pig-iron, only sulphur, phosphorus, and copper need be considered in practice. From the commencement of the process, sulphur gradually disappears as sulphurous acid, but a small part always remains pertinaciously in the iron. Phosphorus and copper remain in the iron unchanged. The first is indeed oxidized at the commencement, and passes into the slag as phosphoric acid, but at a higher temperature it is again reduced and passes back into the iron.

Other bodies appear only in very small quantities in pig-iron, and in practice are of no importance ; but still, in so delicate a process as spectral analysis, they cannot be disregarded. To these belong nickel and cobalt, which, being more difficult of oxidation than iron, remain in the product in the metallic state ; titanium, arsenic, and antimony, of which the first is oxidized, and the last two volatilized ; aluminium, magnesium, calcium, potassium, sodium, and lithium, which partly pass into the slag, and partly pass off with the gases in the form of vapor.

To these are added the constituents of the fire-proof lining of the converter, essentially silicic acid and alumina ; but, besides these, also manganese, iron, the earths and the alkalies in greater or smaller quantities ; and, finally, the blast carries with it, besides nitrogen, which passes off unchanged, vapor of water, whose hydrogen is contained in the gases. It is not improbable that free oxygen sometimes issues out of the metallic bath, but this probably ceases to exist as such inside the vessel, chiefly in converting carbonic oxide into carbonic acid, provided the temperature be not, perhaps, too high.

Conclusions as to the Character of the Spectrum.—During the entire process, with the exception of the first and last period, glowing gases and vapors stream out of the converter. Among these, next to nitrogen, carbonic oxide is present in the greatest quantities. In these gases, all those bodies which give characteristic lines by the refraction of their rays through a prism, will show, on observation through a spectroscope, these lines simultaneously.

But besides these gases, a quantity of glowing solid or molten bodies (iron, slag, etc.) is almost always in the stream of gas. These must produce a continuous spectrum, but since they are mostly subordinate to the gas, the bright lines produced by this last will appear on a continuous spectrum, serving, to a certain extent, as a background. The brightness of the lines, diminished by this means, is still further decreased by the diffused sunlight, which, in the observations during the day time, also gets into the spectrum, and increases the brightness of the continuous spectrum.

The glowing gases cool quite rapidly at the edge of the flame. This is shown by the forked appearance of the edges during the second period. The rays of the glowing body in the interior consequently fall through a stratum of gas, which, being of the same composition as the former, must absorb its rays, so that, instead of bright lines, dark bands of absorption may appear in the spectrum. This will be the case more or less, according to the

thickness or density of the non-luminous stratum of gas. If this stratum is sufficiently powerful to entirely absorb the characteristic rays of the glowing gases, then between the dark bands of absorption we will have the non-absorbed rays of the continuous spectrum, and these might, in consequence of their apparent brightness, the result of contrast, be taken for real lines. If the stratum does not absorb sufficiently, then the real bright lines will appear but faintly. This last may be expected as most probable.

OBSERVATIONS OF THE BESSEMER SPECTRUM.

To aid in comprehending the following discussion, we have represented in Fig. 1 the continuous spectrum, produced by sunlight, or by any incandescent body. The most important lines of absorption, the so-called Frauenhoffer lines, are also represented, and marked with the usual letters. These last will be used without further additions to designate the position of definite lines. When lines lying close to each other give the impression of belonging together, be this due to their general appearance, or to their being separated by a space from other lines, they will be designated as groups of lines. Such groups often show a greater brightness on one side than on the other. This appearance is characterized by the term shaded. When "right" or "left" is mentioned, "right" always means towards the most refracted part of the spectrum, *i. e.*, the violet; "left" means towards the least refracted part of the spectrum, *i. e.*, towards the red.

General Characteristics of the Bessemer Spectrum.—At the commencement of the charge only a faint continuous spectrum is visible. It is only towards the end of the first period, simultaneously with the commencement of a decided flame, that characteristic bright lines begin to present themselves. At first the sodium line D appears alone; flashing up, and then disappearing for a moment, it soon remains steady with a brightness increasing with the development of the spectrum. It is visible during the entire process, is seen longer than any of the other lines, and sometimes does not disappear even at the end of the reaction. Soon after this line, other lines appear in the greenish yellow and green part of the spectrum. These lines are separated from each other by shaded bands, and are sometimes so faint, that one might feel inclined to take the bands for products of absorption, and the lines as the remains of the continuous spectrum. Gradually two lines can be distinctly recognized; then the shaded bands resolve themselves into other lines with spaces between them, and groups of lines are formed, one in the yellowish green, the other in the green. With the increasing brightness of the flame, and the continuance of the process, the groups of lines resolve themselves into a large number of lines with separating bands, at the same time the spectrum of the lines expands itself. Another group of lines appears in the bluish green, and a few lines can even be recognized in the bright blue. If the spectroscope be sufficiently strong, soon after the appearance of the sodium lines the characteristic lines of potassium and lithium may be noticed in the red, and in the violet a second line characteristic only for potassium. Simultaneously with the first bright lines in the yellowish green and green, a line may be observed in the violet near the potassium line β, but more strongly refracted than this last.

It is claimed that during the third period when the flame is most brilliant, still more lines are sometimes visible in the dark blue and bluish violet. An ordinarily good spectroscope does not show these lines, nor indeed some of the others; the sodium line, however, and the three groups in the yellowish green, the green, and the greenish blue, can still be recognized, even when the charge shows considerable smoke.

With the decreasing brilliancy of the flame in the last period, the characteristic lines of the spectrum disappear in the inverse order of their appearance, but in much shorter intervals. The disappearance of the groups of lines in the yellowish green and green (these made their appearance first) indicates that the process is ended, and on turning the converter down, the sodium line generally, though not always, disappears.

The flame which forms when the spiegeleisen is let in, generally shows with more or less distinctness the same spectrum as that observed in the second period of the process.

The Bessemer Spectrum according to Roscoe.—All we learn from Roscoe's report

concerning his observations of the Bessemer flame at Brown's Works in Sheffield, is that the characteristic lines appear in those places where lines due to carbon, iron, sodium, lithium, potassium, hydrogen and nitrogen, appear in the spectrum. In this case, therefore, we have no starting-point to aid us in forming an opinion.

According to Watt.—Roscoe's assistant, Dr. Watt, continued the observations, and gives the following description of the spectrum :

At the commencement, a continuous spectrum is visible. After 3 or 4 minutes the sodium line appears, at first flashing out and then disappearing, but soon steadily visible. Hereupon a very great number of bright lines and very dark bands appear, which increase in distinctness till the end of the process. At the termination of the process, on the other hand, all the dark bands and most of the bright lines disappear. The spectrum is characterized by the complete absence of all lines in the refracted parts, and extends hardly any further than Frauenhoffer's line *b* (in the green).

That this last-mentioned peculiarity, which Watt is inclined to consider characteristic, results only in the instrument used, is shown by the remarks further on.

It has, moreover, been mentioned above, that in the case of charges disposed to show a good deal of smoke, the more strongly refracted lines cannot be seen even with a good spectroscope.

The spectrum which is visible before the close of the oxidation process is represented in Fig. 4, according to an enlarged drawing by Watt. In connection with this, Watt remarked that the bright bands appear at the time of greatest development, as groups composed of numerous lines.

From the figure it will be seen that the sodium line is strongly developed. To the left of it there is another group of lines which do not extend quite up to *c*. Between D and F there are 5 shaded groups, 4 of which lie between D and *b*, with the brightest edge to the right, and the 5th between *b* and F, its brightest part being in the middle. To the right of F there is still a faint line in the blue. After letting in the spiegeleisen, the spectrum shown by the ordinary flame during the oxidation period some times reappears, according to Watt, but more generally the spectrum is apparently quite different. On close examination, however, it may be seen that, although the general appearance is quite different, yet the lines of the two spectra agree.

This spectrum of spiegeleisen is represented in Fig. 5. We notice the perfect coincidence of the group of lines to the left of D. On the other hand, we observe that the 5 other groups are much more clearly defined, so that it gives the impression that we here have a simpler spectrum, which becomes complex during the process by the addition of other lines.

According to Zielegg.—Zielegg made his observations, as has already been remarked, at the Bessemer works, in Gratz, where grey charcoal pig-iron was used. His exact and reliable investigations gave the following results :

At first only a faint continuous spectrum can be noticed. The yellow can scarcely be detected, the blue and violet are weak, and even the sodium line is lacking. Gradually the brightness increases, and with it the continuous spectrum becomes more distinct. With the first slag discharge, soon after, the sodium line flashes up, and after 1 or 2 minutes remains steadily visible. This is the commencement of the second period. At the same time the potassium lines α and β, in the red and violet, appear.

In the boiling period the sodium line becomes so bright that it surpasses in brilliancy those parts of the spectrum lying nearest to it. In the yellowish green, in the green and in the blue, lines appear which form groups of threes and fours, about equally distant from each other. Of the groups in the greenish yellow and green, only one line appears at first in each, the others then follow gradually.

At the end of this period, these groups of lines are quite distinctly visible, but they are most distinct in the third period, at which time the lines in the blue also show themselves. The bright part of the spectrum now appears, divided in four groups of equal size. One lies in the neighborhood of the sodium line in the yellow, and is bounded on the right by a bright yellow line. The second group is in the greenish yellow, and is characterized by three broad lines, of which the third (the one furthest to the right) is the brightest. In the third group there are four greenish blue lines, of which the one next to the

last is the brightest. The fourth group contains four blue lines of equal brightness. The intervals between the lines of the third and fourth groups appear dark and look like lines of absorption.

In the more strongly refracted parts of the spectrum, besides the potassium line β in the violet, another still more strongly refracted line may be recognized, which makes its appearance already at the commencement of the boiling period. During the time of most energetic reaction, in the last period, a sharply defined line in the blue violet is added, while in the less refracted part of the spectrum, to the left of the sodium line, in the orange red (about the place of calcium a) two or three lines are visible, lying closely together and not sharply defined.

The most completely developed spectrum, such as is only seen with a very perfect apparatus, and with charges showing little smoke, has been drawn by Zielegg with great accuracy, and since it has found general confirmation, it has been given in Fig. 2.

The order of the appearance of the various bright lines has been represented in the following table in such a manner, that those placed furthest to the left appear first, and those furthest to the right, last:

Scale of Fig. 2.	Slag Period.		Boiling Period.						Mark of the Scale
Group Mark.	1.	2.	1.	2.	3.	4.	1.	2.	
		Potassium α.							30.40
		Lithium α ..							27.8
α 25.7						Red lines sharply defined; 1st and 3d the plainest			25.7
α 25.5									25.5
α 25.3									25.3
24.9 ..				Dark band not sharply defined					24.9
24.6 ..	Sodium line								24.6
24.5 ..				Narrow dark band ..					24.5
β 24.0					Yellowish green lines				24.0
β 23.5									23.5
22.9 ..			Brightest line in β..						22.9
γ 21.9					Light green lines				21.9
γ 21.7									21.75
γ 21.65 ..			Brightest line in γ....						21.65
21.2 ..							Bright green lines ..		21.2
δ 20.7					Greenish blue lines				20.7
δ 20.5									20.5
δ 20.3									20.3
δ 20.05									20.05
ϵ 19.3					Light blue lines				19.3
ϵ 18.95									18.95
ϵ 18.6									18 6
ϵ 18.15									18.15
15.8 ..						Group of blue lines stopping at 15.8.			15.8
ζ 12.6						Four blue lines			12 6
ζ 11.2									11.2
8.6 ..								Bluish violet line ..	8.6
4.9 ..		Potassium β							4.9
η 4.7 ..			Bright violet line						4.7

Towards the end of the third period, the brightness of the groups of lines diminishes, and they disappear in the order of their appearance (consequently in the above table from left to right). Shortly before the completion of the charge, all the lines of the third and fourth are no longer visible, and the spectrum assumes the appearance it had at the commencement of the boiling period (1). The vanishing of the last of these lines marks the completion of the oxidation process.

Comparing Zielegg's spectrum with that of Watt, we find that the dark band to the

left of the sodium line at 24.9 of the former is wanting in the latter; that the group α extends in Watt's spectrum to 27.5, consequently further to the left than in Zielegg's spectrum, and shows furthermore a greater number of bright lines. The group β agrees in its extent, though not in its single lines. By Zielegg, group γ is narrower and more sharply defined than by Watt. Groups δ and ε agree in their main points. The blue group stopping at 15.8 is represented by Watt as being less developed, and all the lines lying to the right of it are entirely wanting. The light green line of Watt at 21.2 is not marked down by Zielegg, but is mentioned in the description. The single bluish green line of Watt at 19.6 is entirely wanting with Zielegg.

Later Observations.—All later observations in regard to the appearance of the spectrum, confirmed what Zielegg had established with such great care. From the "Maximilianshütte" in Bavaria, Blerchsteiner, and from Seraing, in Belgium, Habets, report similar observations. The observations at Neuberg and at the Königshütte also gave no contradictory result, although the hopes entertained of the usefulness of the spectroscope in judging of the process, was considerably toned down. This was in consequence of the slight development of the spectrum and of the disappearance of the characteristic lines before sufficient decarbonization, as soon as the charges smoked considerably. In point of fact, numerous observations made by Sattler and Hasenöhel, at "Königshütte," have shown that with cold charges and the production of soft steel, the disappearance of the lines in the green and greenish yellow coincide exactly with the time at which a skilful engineer, judging from the appearance of the flame, gave the order for turning the converter. On the other hand, they did not succeed in finding lines whose disappearance would mark the point of interrupting the process for the purpose of producing the harder qualities of steel, although this point could be determined with sufficient accuracy with the eye. With hot charges, showing a good deal of smoke, and with iron directly from the blast furnace, the disappearance of the lines occurred so soon that the interruption of the process, according to these signs, gave entirely wrong results; that is to say, a product which was not sufficiently decarbonized. At Neuberg, on the other hand, under similar circumstances, the product was burnt (*i. e.*, the decarbonization had proceeded too far), even though the engineer who had conducted the operations at Gratz, where the spectroscope had given such practically useful results, had assisted at Neuberg.

Finally an appearance must be mentioned, to which Kupelwieser has already called attention, and which the author has frequently had occasion to observe at Königshütte. It is the peculiarity, that the groups of lines lying in the yellowish green, the green, and the bluish green, do not disappear *gradually*, as Zielegg says, but vanish suddenly to reappear at the next moment, though fainter than before. This vanishing and reappearing continues, the lines growing fainter till they disappear entirely from the spectrum. This, of course, greatly hinders the correct determination of the point for ending the process. The same remark is true of the sodium line. It also disappears for a time and flashes up anew, just as it always does at the commencement.

The Spectroscope.—On account of the small field which contains the clearly visible and characteristic lines of the Bessemer spectrum, it is necessary that the spectrum should be considerably extended in length. The apparatus first employed at the Königshütte, did not answer, because, by the refraction of the rays through a single prism, the spectrum was too short, and the lines lay too close together to be distinguished from each other. Although, on account of the great brightness of the Bessemer flame, its spectrum may, without injury, be considerably lengthened by means of several refractions, it is nevertheless not advisable in practice to have too great a field of view, since it makes the observation more difficult and draws away the attention from the most important point.

A refraction of the rays through two prisms is to be recommended most for apparatus to be practically in Bessemer works. The apparatus in use at the "Königshütte" was made at the workshop of the Imp. Polytech. Inst., at Vienna, by Messrs. Starke and Kammerer. To protect the prisms against dust and dirt, they are enclosed in a wooden box furnished with a lid. From this box tubes protrude, one to receive the rays before refraction,

the other to bring the spectrum to the eye. The axes of these two tubes are at right angles to each other. During the observation the whole box is placed on a tripod, furnished with a ball and socket joint. The slit through which the rays of light pass into the tube may be increased or diminished by means of a thumb-screw and a spring. The rays are refracted by means of two flint-glass prisms whose sides are $1\frac{1}{2}$ in. long, and whose height is $1\frac{1}{2}$ in., and then passes into the telescope, which magnifies 6 times. Through this telescope, which can be regulated to suit the eye, the spectrum is observed. In order to be able to compare the Bessemer spectrum with that of other bodies, a small prism is placed before the slit of the tube for admitting the rays, and partially covering it. Thus, two spectra, situated one above the other, are obtained. When in use, the apparatus is mounted 20 to 30 ft. from the converter, and the tube with the slit is directed to the rim of the central cone of the flame.

Habets recommends an arrangement of the spectroscope made by Browning and Sorby in London, and successfully used at Seraing. In this instrument, the axes of the telescope and of the receiving tube are in the same vertical plane, an arrangement which enables the operator to make his observations with more ease when the instrument is to be held in the hand.

DEDUCTIONS FROM THE OBSERVATIONS.

Sodium, Potassium, and Lithium Lines.—There is no doubt that the bright lines heretofore ascribed to sodium, potassium, and lithium, really belong to these bodies. A direct comparison shows their perfect coincidence. These bodies may be partly derived from the iron, but beyond doubt they come chiefly from the fire-proof material with which the converter is lined. Already, during the warming of the converter, and even when the lining is entirely new, the flame produced by the burning of the charcoal or coke contained in the converter, shows them in its spectrum.

Iron Lines.—The iron spectrum, according to Thalèn, is represented in Fig. 6. On account of its numerous lines, many of which are found in the green (a part in the Bessemer spectrum also rich in lines), it is difficult to determine the coincidence of the two spectra, and if this exists, to determine how far it goes, since the characteristic iron lines in the blue and bluish violet do not harmonize with the few lines of the Bessemer spectrum in these parts.

Watt has called attention to the circumstance that the line situated at 21.2, between the third and fourth groups, and to the left of E, one of the lines of the group δ, situated between E and b, and a third line at 19.6 to the right of b, must belong to iron. Furthermore the bluish green lines of Zielegg, between 17 and 18, might also belong to iron. In point of fact it would be very surprising if no iron lines could at all be found. Numerous as the lines of iron are between E and b, they still agree so little in their general appearance with the most characteristic lines of the Bessemer spectrum, that it gives room to the supposition that the brightness and size of the lines of the Bessemer spectrum do not allow the iron lines to appear.

Watt compared the spectra produced by passing an electric spark between two iron poles in the air, and between two iron poles in hydrogen gas, with the spectrum of the Bessemer flame, and found only the three lines mentioned above to agree.

Lines due to Carbon and its Combinations.—It is natural to ascribe the characteristic lines of the spectrum to carbon, or its combinations. On the oxidation of carbon the entire success of the Bessemer process is based, and Zielegg, with reason, calls attention to the circumstance that so steady a spectrum as that visible from the beginning of the boiling period to the process, can hardly be ascribed to any other bodies than carbonic oxide or nitrogen, since no other body can be present in such great quantities in the Bessemer flame. Since nitrogen gave no spectrum, either on burning its combinations, or a body rich in nitrogen, he concludes that the lines must be ascribed to carbonic oxide gas. For this argument, Zielegg found another proof in the fact that the characteristic groups of lines of the Bessemer spectrum (although not so well developed) showed themselves in the carbonic oxide flame, produced during the warming of the retort with charcoal and coke.

Roscoe, Watt, and others, did not doubt the correctness of this explanation. Schlenz found its confirmation in the

fact that other flames, consisting principally of carbonic oxide, as, for instance, the tymp flame, the flame at the throat of a blast furnace, that of the furnace gas for heating the blast and boilers, that of the English finery fire, etc., gave spectra that coincided very nearly, or entirely, with the Bessemer spectrum. Kupelwieser thought he had proved it by an experiment on a small scale. On a small Leffstroem assaying furnace he placed a truncated cone line, with fire-proof material, and 3½ inches high, and compelled the gas to pass through a small opening, 1 to 1¼ in. in diameter. The spectrum of this flame is said to have given the groups *a*, *β* and *γ* of Zielegg. This last experiment would have had the greatest value as a proof if it had been made with a complete —not, as mentioned, with a very small apparatus, and had been supported by figures; for the eye alone, without the aid of a scale, is only too apt to lead astray in spectral analysis. Furthermore, this gas, just as the gas produced during the warming of the converter, is no pure carbonic oxide gas, but one that has come in contact with particles of clay and iron. Consequently we have no guarantee that it is free from particles due to these substances.

In spite of all these hypotheses in favor of the appearance of a carbonic oxide spectrum during the Bessemer operation, it was still remarkable that the burning of pure carbonic oxide gas in a stream of oxygen gave no characteristic spectrum. It is well known that in this case only a continuous spectrum was obtained, in which the green and blue parts were particularly developed. The comparison also which Watt made between the Bessemer spectrum and the spectrum of an electric spark in carbonic oxide, showed no resemblance between the two.

Brunner has, with reason, remarked that we cannot, with Zielegg, seek for the cause of this difference in the higher temperature of the Bessemer flame, for otherwise it would be necessary to assume that the burning of a mixture of pure carbonic oxide and oxygen produces a lower temperature, which is improbable. At any rate, this latter temperature must be higher than that produced during the warming of the converter, yet the flame then produced shows the characteristic lines.

Another remarkable fact, which, however, is only apparently against the assumption of a carbonic acid spectrum, is in the non-agreement of the Bessemer spectrum with other known spectra due to carbon. In regard to the shading of the groups of lines, we notice just the contrary. In the Bessemer spectrum the shading is from right to left; in other spectra due to carbon, from left to right; so that in the first case we have the brightest line to the right, that is refracted most, and in the others it is to the left, that is refracted least.

This difference was noticed by Watt in the examination of the spectrum produced by burning a mixture of olefiant gas and oxygen before the oxyhydrogen blow-pipe, and also by Zielegg himself in his comparisons with the spectra of carburetted hydrogen, of elalyl, and of cyanogen. From it Zielegg concluded that the spectrum of a carbonic oxide flame was a very peculiar one, and was to be regarded as a spectrum due to *glowing carbonic oxide*, and not to carbon. This inference must be mentioned here, for it cannot be contested in itself, and would give a sufficient explanation of the Bessemer spectrum, if this were, in fact, the result of carbonic oxide.

Lines of Manganese.—It was Brunner, in Neuberg, who first pointed out that the reasons above set forth were scarcely sufficient for attributing the characteristic lines to a carbonic oxide spectrum, but that they must be due to some other bodies contained in the pig-iron. "The very appearance of these lines in the spectrum of the flame, produced in warming a converter whose lining had already been used, as noticed by Zielegg, and their absence on warming a converter whose lining was entirely new, is a proof," Brunner concludes, "that they result, not from the carbonic oxide produced in both cases, but from the scales of metal remaining in the converter after having been used. Since the known iron lines did not suffice for an explanation, it was not far-fetched to think of the manganese spectrum, more especially since the violet line belonging to it seemed to coincide with the line *η* of Zielegg."

That manganese is really volatilized, and in part passes off in combination with silicic acid and protoxide of iron, has already been mentioned at the commence-

ment of this article. The assumption of Brunner was entirely justifiable in itself, and only needed proof, that is to say, a comparison. The first examinations of the manganese spectrum were made by Theo. Simmler. He describes the spectrum as follows: "We have 4 comparatively broad green lines crowded together, and only at a great distance, in the outer violet, another isolated, narrower, but bright line." It turns out that the first two lines lie in the light green, and the fourth in the bluish green part of the spectrum, and that the violet line is situated near the potassium line β, without coinciding with it. 0.012 milligr. of manganese still gives the first two lines quite distinctly.

Besides this, we have spectra of manganese by Huggins and by Robert Thalèn, and their most important lines are delineated in Figs. 7 and 8. Irrespective of the fact that the two spectra do not agree—for Huggins gives two principal groups between C and D, and Thalèn only one, while the violet line, lying close to the potassium line β, is not at all noticed by Huggins—like most of the complicated spectra represented by simple lines, they are not sufficiently characteristic for purposes of comparison.

Hasenöhel examined the manganese spectrum anew at the "Konigshütte," but because the spectroscope lacked a scale for measuring, only the supposition, not the certainty, that it agreed with the Bessemer spectrum could be announced. On this account further observations were made here (at Berlin), which gave the spectrum represented in Fig. 3. This was produced by heating chemically pure chloride of manganese, moistened with pure hydrochloric acid, before an oxyhydrogen flame issuing out of a glass stopcock. In order to fix the lines that appeared till their position could be read off on the momentarily illumined scale, it was necessary to determine the position of the substance (placed on a moistened platinum wire) by experiment. The agreement of the principal lines, especially of the bright bands in the characteristic group β, the coincidence of the shading from right to left which appears exactly as in the spiegeleisen of Watt, and the similarity of the entire appearance, show the identity of the larger part of the Bessemer spectrum with the spectrum of manganese. In observing the simple manganese spectrum, it has also been found that the number of lines into which the four groups resolve themselves, increase with the increase of temperature. The violet line agrees exactly with that of the Bessemer spectrum. Whether the lines in the reddish yellow, which agree better with the spectrum of Watt than with that of Zielegg, are due to indiscoverable traces of calcium (as Simmler has assumed), need not be discussed; but it is not probable, since both Huggins and Thalèn have marked down a group of lines in the same spot. Nevertheless, it would not be surprising if, on account of the calcium always contained in the fireproof lining, the Bessemer spectrum should show lines belonging to this body. The experiment of Lichtenfels, however, speaks against this assumption. On direct comparison of the Bessemer spectrum with the spectrum produced by burning chloride of calcium in an alcohol flame, he failed to find any coincidence in the lines. Comparing the lines of Zielegg's Bessemer spectrum with Thalèn's calcium spectrum, the bluish violet line 8.6 seems to agree sufficiently. It is possible that only at the high temperature which exists when this line appears, calcium vapors are formed, but that then, the characteristic lines of calcium α and β to the left and right of D, in the bright part of the spectrum, are suppressed by the brilliancy of D. The manganese spectrum becomes remarkably like the Bessemer spectrum, if the sodium and potassium lines are produced simultaneously, the platinum wire being at the same time made to glow slightly. The bright lines then lie on a faint, continuous spectrum. By causing the wire to glow more brightly, the continuous spectrum becomes so brilliant that the bright lines are no longer visible, though at the same time it is impossible to discover lines of absorption corresponding to these lines.

If, now, there could have been still any doubts that the Bessemer spectrum was, in its principal points, a spectrum of manganese combined with lines of iron, potassium, sodium, lithium, and perhaps calcium, these were entirely removed by a series of simultaneous comparisons of the manganese and Bessemer spectra in the same spectroscope, made by A. V.

Lichtenfels. Lichtenfels found not only a general agreement between the four characteristic groups of lines of the Bessemer spectrum with the four bands already noticed by Simmler, but also that the single component lines into which the groups resolved themselves, harmonized completely in the two spectra. Two of the groups he found very distinct; the other two situated towards the blue were fainter. The violet line could not be detected either in the Bessemer spectrum or in that of manganese with the apparatus used. In regard to this last, however, our own observations do not admit of a doubt as to their identity.

Bands of Absorption.—The bands lying between the principal groups of the Bessemer spectrum might be bands of absorption. In this case, however, in the manganese spectrum they would also be due to absorption. This might be possible, in consequence of the formation of glowing particles of manganese during the volatilization of the chloride of manganese in the oxyhydrogen or alcohol flame; but even in this case nothing would be changed as to the identity of the two spectra.

According to Watt, the dark band at C shows itself especially during damp weather, and since it agrees with the red band of hydrogen, he considers it a band of absorption.

That the sodium line can also appear as a line of absorption is only mentioned by Roscoe. The author has never found it to be the case. There is still less ground for the assumption of the same chemist, that other dark lines are absorption lines due to carbonic oxide, than that the bright lines are to be attributed to carbonic oxide gas.

The two dark bands lying at the side of the sodium line (at 24.9 and 24.5) impress one most as being bands of absorption. If this supposition is correct, it still remains to be proved to what bodies they belong. The spectra delineated by Kirchhoff, Thalèn, and Huggins, give no explanation on this point.

From what has been said above, it is probable that lines of absorption are only the exceptions. There is certainly no ground for inclining to the assumption suggested by Habets as not unfounded, that the bright lines of the Bessemer spectrum are the remains of a continuous spectrum appearing between lines of absorption. Were this the case, the lines of the alkalies would first of all be present as dark bands, and not as bright lines.

Origin and Disappearance of the Spectrum.—As long as the Bessemer spectrum was considered as a carbon or carbonic oxide spectrum, the explanation of the origin and disappearance of its characteristic lines was very easy. It is well known that the oxygen of the air oxidizes the carbon of the iron by the agency of protoxide of iron, which forms first, and is easily dissolved in a singulo-silicate slag of the protoxide of iron. To bring forth the carbon reaction, a slag must be first formed; that is, the silicon of the pig-iron must be mostly oxidized. Since this takes place in the period of slag formation, the deduction may be drawn, that during this time no carbon is contained in the flame. When the iron is entirely decarbonized, no carbon can be contained in the flame, and the lines must again disappear.

Brunner pointed out that the iron called in practice decarbonized, still contains no inconsiderable amount of carbon. According to four analyses which he has communicated, the percentage of carbon sank first from 3.930 to 2.465, then to 0.949 and finally to 0.087, before the addition of spiegeleisin. A quantity which, according to his opinion, would still produce a sensible reaction on account of the delicacy of the spectral apparatus, provided the brightness of the flame were sufficient.

Schlenz, on the other hand, starting with the assumption of a carbonic acid spectrum, thought the cause of the late appearance of the lines was to be found in the proportion between the carbonic oxide and the carbonic acid formed. He says: "In the first period but little carbon is burnt in comparison to the other bodies taking part in the operation, and this is probably not oxidized to CO, but directly to CO_2. For this, the circumstance that a large quantity of unburnt air passes through the metal bath and out at the mouth of the converter, would be more than convincing. In this case the lines characteristic for carbonic oxide cannot appear in the spectrum of the flame, or they are so faint that they cannot be noticed. On this same account changes can take place in the spectrum during the specific carbonic oxide period, according

to the measure in which carbonic oxide gas and carbonic acid are formed; but since now the formation of carbonic acid falls considerably below that of carbonic oxide gas, these changes cannot be noticed, at least not with the instruments employed up to this time.

"Turner's opinion, that only carbonic oxide is formed, may be correct for the use of charcoal pig-iron, whose period of emission of sparks is always short, but not for the conditions of "Königshütte," where only coke pig-iron is employed. The qualities of the coke pig-iron employed at "Königshütte," have always been distinguished from charcoal pig-iron in having a comparatively long spark period, during which the metal has time to become thoroughly warmer, so that on this account it gives a warm steel, and a smaller percentage of waste and of scales in the casting pan. But with this kind of iron a large quantity of undecomposed air doubtlessly passes through the metal bath at the commencement of the process; that is during the spark period. Of this fact one may easily convince himself by means of the sparks of iron. If we take such a position as to be able to see into the mouth of the converter, we notice that a large number of iron particles of the size of filberts are thrown from the surface of the metal to the upper parts of the sides of the converter, where they burn up slowly, and give rise to the sparks that form the well-known stream of sparks outside the converter. Since this oxidation, which can be observed with perfect distinctness, commences in the converter itself, and is continued outside of it in the stream of glowing gas, we are warranted, if not forced, to assume that it can no more be the external air which alone causes these sparks, than that the sparks could be formed in the converter, if this were only filled with decomposed air and other gases not containing free oxygen. Hence the sparks can only be originated by the blast, a part of which passes through the metal undecomposed. Now, if this takes place, it is admissible to suppose that a small quantity of carbon oxidized at the commencement of the process, is oxidized directly to carbonic acid. On this account no carbonic oxide lines, or very few, will be noticed in the spectrum of the flame at the commencement of the process.

Just as in the commencement it cannot be observed, and only develops itself slowly, in the same way towards the end of the process when only very little or no carbon is present to be oxidized, the carbonic oxide gas spectrum must become faint, and at last entirely disappear, or at least be darkened by the remaining lines of the spectrum of the simply luminous flame, or of the glowing mixture of gases.

With the determination that we have no carbonic oxide spectrum to discuss, all these explanations become unnecessary and not to the point, and there are only left the following modes of explanation:

1. The luminous power of the flame at the beginning and end of the process does not suffice to produce the spectrum. 2. At these periods we have no flame (*i. e.*, a luminous stream of gas), but only an illumined stream of gas. 3. The temperature at the beginning and end of the process, is not sufficiently high to volatilize the bodies producing the spectrum. 4. The absolute quantity of the bodies volatilized producing the spectrum is at this time too small.

As regards the luminous power of the flame, which Brunner takes as the explanation, this is certainly very small at the commencement of the process. At the end, however, in a great many cases, and perhaps in all, it remains pretty strong. It is true that the luminous power of the flame at this time diminishes, but it is decidedly always greater than at the commencement of the boiling period, and then the spectrum is already well developed. This may be readily proved by the photometer. Sometimes (as at Hörde) the flame has considerable brilliancy. Only when a very heavy smoke is developed, is the luminous power considerably diminished, and then the disappearance of the lines is sufficiently explained. In other cases the explanation does not suffice.

In the second section of this article it has already been pointed out that the stream of gas issuing in the first period cannot be regarded as a flame. The gases are not yet in a glowing state, and no combustible gas is present which could burn in the upper part of the converter, or at its mouth. So far the second explanation would meet the case. In the same manner at the end of the process only an illumined, not a luminous, stream of gas appears; but

though the lines of the alkalies (consequently those due to the lining of the converter) remain up to this point, yet the manganese lines disappear before this point is reached. The disappearance of the lines cannot, therefore, in general, be explained by the lack of a flame.

The luminous power of a flame does not depend on the temperature, but essentially on the composition of the gases. It is well known that the luminous power and the temperature are only related in a flame of the same gas. On this account ascribing the appearance and disappearance of the lines to the differences in temperature does not amount to the same as ascribing these circumstances to the varying luminous power of the flame. But also the temperature gives no sufficient explanation, for Schlenz has pointed out that the flame during the warming of the converter, and the tymp flame of the blast furnace, are decidedly not as hot, and yet give the same characteristic lines as the Bessemer flame, while, on the other hand, the flame of the English finery fire, though one of the hottest, shows these reactions less distinctly.

If, therefore, the gradual appearance of the lines at the commencement of the process may be explained by the lack of a flame, by inferior luminous power, and by the lower temperature, then the only explanation left to account for the disappearance of the lines (except in the case of a great deal of smoke) is the small absolute quantity towards the end of the process of the body to be volatilized.

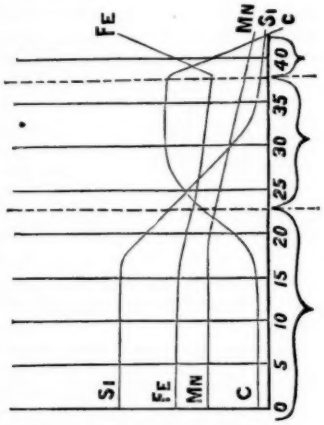
Evidently there can be no discussion as to the entire disappearance of the substances producing the spectrum. Iron is always present, as is also manganese, as shown in the analysis communicated by Brunner, giving, for instance, in decarbonized iron, 0.113 per cent. of manganese, and in the slag, 32.23 per cent. of protoxide of manganese.

Furthermore, it is known that spectral analysis requires a certain quantity of substance, varying greatly with different bodies. A trace of sodium will give its characteristic line, but, according to Simmler, a much larger quantity of manganese is needed to obtain a recognizable reaction, than that which can be detected by the well-known blow-pipe reaction with carbonate of soda. Consequently, spectral analysis does not depend solely on the *presence* of a body, but also on the presence of a certain quantity.

Schlenz probably first pointed this out in reference to the Bessemer spectrum. He says: "It would seem as if the absolute quantity of the body submitted to oxidation, had an essential influence on the appearance of the flame and on the lines of the spectrum. The division of the process into periods is motivated by the changes in or about the flame, observable with the naked eye, and due to the substances momentarily oxidized. For though it cannot be doubted—and every practitioner will have convinced himself of it by inspection—that from the commencement of the process to its entire completion, all possible chemical changes take place at the same time side by side; that from its commencement to its end, iron, carbon, silicon, manganese, etc., are constantly being oxidized, while the blast is constantly being decomposed; yet it can be just as little denied that according to the degree in which one or the other reaction excels in force, the flame must assume a different character. From this it can be deduced that the appearances in the spectroscope corresponding to these reactions in the converter, must show themselves simultaneously side by side, but that at different periods different appearances would principally be visible. According to the bodies concerned, the intensity of the oxidation, or the measure of the quantity oxidized in a unit of time, varies in the different periods of the process. This may, perhaps, be graphically represented by the following sketch.

This diagram says nothing more than what is daily observed: that at the commencement the oxidation of silicon is very energetic, while that of carbon remains in the background, while, at the same time, iron and manganese are pretty constantly oxidized. In the measure that the flame changes, that is, in proportion as the second period is introduced, the ratio between the quantity of silicon and carbon oxidized becomes inverse. At the same time the oxidation of iron and manganese is somewhat reduced. Finally, in the third period the oxidation of carbon nearly becomes a minimum on account of a lack in this body; that of manganese and silicon becomes less on this same account (the proportion of silicon being modified

by its greater or lesser degree of combustibility of this temperature which has now reached its maximum); and, finally, only the iron is oxidized, that body being present greatly in excess of the others.



PERIOD OF FORMATION OF SLAG.

Let us now examine in how far this opinion of Schlenz, according to which the absolute quantities of the different quantities volatilized are characteristic, for the spectrum can be applied to the experience that the Bessemer spectrum is mainly due to manganese.

Taking the analyses above cited to our aid, we find indeed that the manganese contained in the iron falls from 3.460 per cent. in the raw material to 1.645, 0.429 and finally to 0.113 per cent. in the decarbonized product; and that the protoxide of manganese in the slag first increases from 37.00 per cent. to 37.90 per cent. and then sinks to 32.23 per cent.; and furthermore that a certain quantity of manganese is to be found in the smoke. How much manganese is really lost by volatilization cannot be determined, since data are wanting as to the absolute quantities of slag and iron, consequently we cannot determine how much manganese has been lost by means of the eruptions.

But since the manganese contained in the pig-iron decreases constantly, and that contained in the slag after the termination of the boiling period also decreases, a considerable volatilization of this body is probable just at the time when the spectrum is best developed. Comparing with this the experiments that can be made in the laboratory, we arrive at the hypothesis, that the oxidized manganese which has entered into the slag is not volatilized, but retained by the slag; can therefore only get into the flame in the shape of solid or fluid combinations, and has consequently no influence on the spectrum. It was impossible to obtain a spectrum with the silicate of manganese and a flame of very high temperature, whereas volatilized metallic manganese (from chloride of manganese) readily produced it. If manganese could have any effect on the spectrum as an oxidized constituent of a silicate, then also the smoke containing protoxide of manganese, instead of darkening the spectrum, would call it forth more distinctly, or, assuming that it is greatly cooled at the edges of the flame, it would produce bands of absorption. If, on the other hand, our assumption is correct, then the characteristic lines will disappear towards the end of the process, as soon as only such small quantities of manganese are volatilized that no spectrum can be produced. This will take place whether the flame is hot or cold, is very luminous or the contrary, or ever so much protoxide of manganese be contained in the slag.

It may very well be possible that this appearance is intimately connected with the formation of carbonic oxide gas, and that on this very account the manganese spectrum gives such good results in judging of the state of the decarbonization under conditions generally favorable.

Manganese becomes volatile at comparatively low temperatures. It exists as a metallic vapor in an atmosphere of carbonic oxide gas; hence, during the warming of the converter, its scales (metallic crusts) give the manganese spectrum; for the same reason the tymp flame, in spite of its low temperature, gives a spectrum. Should there, however, not be a sufficient quantity of protecting carbonic oxide gas, as at the commencement and close of the Bessemer process (and to a certain extent in the lively oxidation of the English finery fire), then the manganese already volatilized will be oxidized, and will have no effect on the spectrum.

This hypothesis—for this explanation does not pretend to be more—would at the same time explain the usefulness of

the spectroscope in the Bessemer operation, under certain circumstances, and also the apparent contradiction between the intended process of decarbonization and the origin of the spectrum through manganese.

A second solution of this apparent contradiction might be found in the following: The percentage of manganese must always have fallen so low that it can produce no spectrum, in order to allow a sufficient decarbonization of the iron. It is known that the silicate of the protoxide of manganese is no solvent for protoxide of iron, and consequently the more it is present in contradistinction to the silicate of the protoxide of iron (an excellent solvent for the protoxide of iron), the more does it hinder or delay the decarbonization of the iron. On this property the most important characteristic of the manganiferous pig-iron used in the steel puddling process rests. Such assumption, however, agrees but little with the experience at Neuberg, where a burnt iron was obtained before the manganese lines had disappeared, and also contradicts the experiments cited above.

At any rate, the important influence of manganese on the decarbonization of pig-iron and on the formation of steel, is not to be mistaken. It plays an important part in all the steel processes, so that, not only for the Bessemer process, but also for Martin's and for still others, spiegeleisen has become indispensable, while at the same time other artificial additions containing oxide of manganese have generally proved ineffective. Hence, the collection of data with the spectroscope as to the role of manganese, is not only of theoretical but of practical importance. Metallurgists are therefore earnestly requested to continue investigations in this direction with the spectroscope.

LEAD IN THE CROTON WATER.—The attention of the Metropolitan Board of Health having been called to the frequent cases of chronic lead poisoning which occur in the city, the chemist to the Board, C. F. Chandler, was directed to investigate both the Croton water and the various hair tonics, washes, etc., with a view to discovering the probable cause.

Accordingly examinations were made of Croton water which had been in contact with lead for different lengths of time under usually occurring circumstances, of which the following are the results:

1. A gallon of Croton water from a lead-lined cistern, in which it had stood several weeks, was found to contain 0.06 grain of metallic lead.

2. A gallon of water which had remained six hours in the lead pipes of the chemist's residence, yielded 0.11 grain metallic lead, a considerable portion of which was visible to the eye, in the form of minute white spangles of the hydrated oxycarbonate ($PbO,HO + PbO,CO_2$).

3. Water drawn from one of the hydrants of the School of Mines laboratory, in the middle of the day, when the water was in constant motion, yielded traces of lead. This water reaches the school through about 100 to 150 ft. of lead pipe.

These results indicate the source of many hitherto unaccountable cases of lead poisoning, and are of a character to alarm the residents of New York, and to lead them to adopt precautionary measures for protection against this insidious cause of disease. Many have already introduced, as a substitute for lead pipe, the "tin-lined" or "lead-encased block tin" pipe.

Certainly no pains should be spared to impress upon servants the importance of allowing the water to run for a few minutes before taking it for drinking or cooking purposes, especially early in the morning after the water has stood all night in the pipes. The habit of filling the teakettle from the boiler, or of using water from the boiler for any purpose except washing, is very dangerous.

Experiment No. 2 explains a case which recently occurred in New York. An elderly gentleman was completely prostrated with paralysis or palsy. His physician at once suspected lead poisoning from his symptoms, and instituted inquiries which developed the fact that the patient had been using wheaten grits for dyspepsia, and that the first duty of the cook in the morning had been to soak them, preparatory to boiling them. She had therefore used daily the water which had stood all night in the pipes. The occurrence of a considerable portion of the lead in experiment No. 2, in suspension, instead of solution, is an additional argument for the use of filters, though it will of course be useless to employ them unless they are frequently reversed, that they may be cleansed.—*Chem. News.*

THE RESISTANCE OF VESSELS.

(*Continued from page 394.*)

It has been shown by Mr. Scott Russell,* that the condition of the broad and rounded parts of a ship, and of her hull between wind and water, is analogous to that of a raft; while the condition of the keel, the sharp part of the floor, and the grip and dead wood (or fine parts of the ends), is analogous to that of the board, floating edgewise, so that the ship is under the action of two conflicting sets of forces—gravity, centrifugal force, and pressure (constituting what may be called stiffness), tending to make her roll with the waves, like the raft—and the action of the water on the keel and sharp parts of the hull, which may be called *keel resistance*, tending to make her roll against the waves, like the board, and hence that she will take some kind of intermediate motion.

It has been pointed out, however, by Mr. Froude and Professor Rankine† that there is an essential distinction between the two sets of forces before mentioned, in consequence of which, though conflicting, they are not directly opposed; namely, that the stiffness is an active force, which tends not only to prevent the ship from deviating from a position upright to the effective wave surface, but to restore her to that position after she has left it, with a force increasing with the deviation; while the keel resistance is merely a passive force, opposing the deviation of the ship from the originally vertical columns of water, with a force depending, not on that deviation, but on the velocity of the relative motion of the ship and the particles of water, and not tending to restore the ship to any definite position. Hence those two kinds of force cannot directly counteract, but only modify one another.

For the mathematical investigation of the action of those forces, reference must be made to the original papers in the "Transactions of the Institution of Naval Architects." The following are the general conclusions:

The permanent rolling of a ship of very great stability, and without any sensible keel-resistance, is governed by the motion of the effective wave-surface, so that she rolls *with the waves*, or like a raft.

When the period of unresisting rolling of the vessel is to the wave period as $\sqrt{2}$: 1, the permanent rolling is wholly governed by the motion of the originally vertical columns of water, so that she rolls *against the waves*, like a board of no stability floating edgewise.

In both of the preceding cases the vessel is upright when the trough or crest of a wave passes her, and her angle of heel is equal to the steepest slope of the effective wave-surface.

When the period of unresisted rolling of the vessel is less than the above value, her upright positions occur *before* the arrival of the troughs and crests of the waves, and her angle of heel is *greater* than the steepest slope of the effective wave-surface.

The greatest angle of heel in permanent rolling occurs when the period of unresisted rolling of the ship is *equal to that of the waves*, and it exceeds the slope of the waves in a proportion which is the greater the less the keel resistance, and becomes infinite when the keel resistance vanishes. Thus, isochronism with the waves is the worst quality that a ship can have as regards steadiness and safety.

When the period of unresisted rolling of the vessel exceeds that of the waves in a greater ratio than that of $\sqrt{2}$: 1, her upright positions occur *after* the arrival of the troughs and crests of the waves, and her angle of heel is less than the steepest slope of the waves.

The forced or passive oscillations of ships are those which produce the most severe strains, because of their continual recurrence; the free oscillations being gradually extinguished by the resistance of the water. It appears, however, that the periodic time of the free oscillations has an important influence on the extent of the forced oscillations, especially in rolling; the most unfavorable proportions for the periodic time of free rolling to that of passive rolling being those which lie near equality, and between equality and $\sqrt{2}$: 1. For the quality of these

* "Tansactions of the Institution of Naval Architects," for 1863.

† "Transactions of the Institution of Naval Architects," for 1863-4.

periods tends to produce an excess of rolling to which it would be difficult to fix a limit; and the ratio of $\sqrt{2}:1$, and those near it, makes the ship roll against the waves, thus throwing her into positions in which there is a risk of the wave-crests breaking into her.

A period of free rolling much less than that of passive rolling gives great stiffness, and makes the ship accompany the motions of the effective wave-surface. A period of free rolling exceeding $\sqrt{2}$ times that of passive rolling is favorable to steadiness, provided that this lengthened period be produced by the inertia of the ship, and not by insufficient statical stability.

The action of the water on a deep keel, on a sharp floor, or on fine ends below water, tends to moderate the extent of rolling produced by coincidence, whether exact or approximate, of the periods of free and passive rolling; but at the same time it lessens the effect of a long period of free rolling in producing the same result.

A deep draught of water is favorable, on the whole, to steadiness, but not to stiffness.

Should the centre of gravity rise and fall relatively to the water in rolling, and the periodic time of the dipping motion so generated happen to be either exactly or nearly one-half of that of the passive rolling, the result will be uneasy motion.

The steady pressure of the wind on the sails promotes steadiness, at a certain angle of heel depending on the moment of that pressure; the sudden gusts of the wind produce lurching.

As to *pitching, scending, and yawing*, it is chiefly important that, for the sake of dryness and safety, those oscillations should be performed in a lively manner among waves; and that object is best promoted by keeping the longitudinal radius of gyration short, as compared with the length of the ship; that is, by taking care not to place heavy weights in her ends.

The true principles of a ship's rolling among waves and their leading consequences were first set forth by Mr. Froude, in a series of papers in the "Transactions of the Institution of Naval Architects," in 1861, '62, and '63. Mr. Froude appears to have been the first to state the proposition that the tendency of the ship to roll among waves is primarily due to her tendency to keep upright to the effective wave-surface, and that the force which induces this tendency is, very approximately, the same as her *stiffness*, or resistance to heeling in still water. The disposition of a ship to follow the average motion of the portion of the wave which she displaces is, however, controlled (as has been pointed out by Mr. Crossland) by the circumstances that the wave water is continually undergoing a deformation of which the ship's hull is not susceptible. Mr. Froude has also shown* that if two plates be hinged together, so that, when in still water, they would float at an inclination of 45 deg. to the vertical, and if the hinge be parallel to the wave-crest, the effect of the wave-motion is simply to open or close the angle between them, and not to alter (sensibly) the horizontal and vertical lines which bisect the angle externally and internally.

As there is nothing to show that the rigidity of the angle between the plates would tend to make any marked alteration in the invariability of direction of the bisectors, the theoretical establishment of this fact is of great importance. Its meaning is, that the effect of bilge-keels is to increase the time, and, in a greater degree still, to diminish the amplitude of the oscillation, and that the use of bilge-keels is the direct mode of effecting this object.

That the problem of safe rolling is not quite the same with that of easy rolling. A roll towards the wave crest is well known as one of the most dangerous things that can happen to a ship in a high-crested sea-way, for the whole crest of the wave may then break in-board. Even when the ship follows the oscillations of the vertical lines, the wave-particles come flat on the ship's bulwarks and side. If she floats quite vertically she is still in the position of a cliff resisting a wave of the same period, whose height is the difference of heights of the surface wave and of the mean effective wave acting upon her.

As regards the impact of a wave, the most violent blow that a wave can give is against a surface parallel to the in-flexional tangent and to the wave-crest, and at a level with the line of inflexion. The

* "Transactions of the Institute of Naval Architects," vol. vi., for 1865, p. 181.

motion of the particles is then normal to the wave-surface. This remark, of course, does not apply to shore waves.

Throughout the discussion of the ship's oscillation among waves, it has been tacitly assumed that the wave-period itself might be regarded as constant. This is very far from either representing the facts, or the practical problem of the ship builder. The wave which the vessel has to encounter may be anything, from the 11 seconds wave, 600 ft. long, to a mere ripple. Practically, a vessel will not roll to waves whose length is much less than her breadth, nor will she pitch much among short waves. But, dismissing these from consideration, it may still be impossible to avoid some contingency in which a ship's period of free rolling may be equal to the wave-period. Obviously, the remedy in this case is for her commander not to keep her *broadside-on*. As a rule, no commander ever would do so in a dangerous sea-way; and even where comfort only is concerned, it is usually open to him either to shorten the effective—that is to say, the *apparent* wave-period—by putting her head a little to the swell, or to lengthen the apparent wave-period by putting her head a little off. He *must* do one of these things if he meets with actual and exact synchronism in anything like heavy weather.

As a practical matter, Professor Rankine remarks: "It would appear that a very close approximation to the form and proportions which are most favorable to steadiness, has, in some cases, been realized by practical trials alone; and that independently of the steadying action of sails; for there are vessels which, when under steam alone, in any moderate swell, keep their decks very nearly parallel to the horizon. It is of great importance that the lines and dimensions, and distribution of the weights of ships, which have been found by experience to possess this excellent quality, should be carefully recorded for the information of naval architects.

"On the other hand, there are vessels (especially screw steamers) whose ordinary extent of rolling each way is from 3 to 4 times the slope of the waves."

On the subject of Waves, we refer to the following papers and treatises:

Weber—"Wellenlehre."

Airy—"On Tides and Waves." "Encycl. Metropolitana" (reprinted in a separate form).

Scott Russell—"Report to British Association," for 1844. Also, "Modern Naval Architecture."

Stokes—"Cambridge Transactions," 1842 and 1850.

Earnshaw—"Cambridge Transactions," 1845.

Froude—"Transactions of the Institution of Naval Architects," 1862, and (incidentally) in his papers "On Rolling." Also, "Remarks on the Differential Wave in a Stratified Fluid," "Transactions of the Institution of Naval Architects," vol. iv., for 1863, p. 216.

Rankine—"Philosophical Transactions" for 1863; "Philosophical Magazine," November, 1864; "Proceedings of the Royal Society," 1868; also, "Shipbuilding: Theoretical and Practical."

Cialdi—"Sul Moto ondoso del Mare."

Caligny—Papers in "Liouville's Journal," 1866.

T. Stephenson—"On Harbors."

With regard to the rolling of ships in wave-water, we believe that almost the only exact investigations are to be found in the "Transactions of the Institution of Naval Architects," some of which have been reproduced in "Shipbuilding: Theoretical and Practical," and reprinted in "The Engineer," and in "Engineering." They are as follows:

Froude—"On the Rolling of Ships," vol. ii., for 1864, p. 180, with Appendices, pp. 45 and 48.

Woolley—"On the Rolling of Ships," vol. iii., for 1864, p. 1.

Crossland—"On Mr. Froude's Theory of Rolling," vol. iii., p. 7.

Rankine—On the same, vol. iii., p. 22. "On the Comparative Straining Action of different Kinds of Vertical Oscillation upon a Ship," vol. iv,, for 1863, p. 203.

Scott Russell—"On the Rolling of Ships," vol. iv., p. 219.

Froude—"Remarks on Mr. Scott Russell's Paper," vol. iv., p. 232.

Scott Russell—Rejoinder, vol. iv., p. 276.

Woolley—Memorandum on same subject, vol. iv., p. 284.

Rankine—"On the Action of Waves upon a Ship's Keel," vol. v., for 1864, p. 20. "On the Uneasy Rolling of Ships," vol. v., p. 38.

Lamport—"On the Problem of a Ship's Form," vol. vi., for 1865, p. 101.

Froude—"On the Practical Limits of the Rolling of a Ship in a Sea-way," vol. vi., p. 175.

Reed—"On the Stability of Monitors under Canvas," vol. ix., for 1868, p. 198.

An abstract of the leading principles will be found as already stated in "Ship-building: Theoretical and Practical," edited by Mr. Rankine.

Some valuable practical observations on the rolling of ships in waves will also be found in a pamphlet, "Du Roulis," by Captain Mottez, of the French Imperial Navy.

MEASUREMENT OF WAVES AT SEA.

This is a thing which has seldom been done with any degree of accuracy. Not only is the vessel moving, but the apparent direction of gravity is not the true one. The result is, that the difference of direction between the tangents to two waves from a point a little behind the spectator is generally taken for the apparent angular height. This may evidently be far in excess of the true apparent height.*

Admiral Paris has invented a self-recording instrument for the purpose of measuring both the height and form of waves. A description of this will be found in the "Transactions of the Institution of Naval Architects," vol. viii., 1867, p. 279. It is unfortunately a differential instrument, without any means of getting a good datum line. It appears to be much better adapted for getting approximate profiles of complex waves than for obtaining accurate measurements of simple ones.

Observations on the lengths of waves present much less difficulty; a float sunk so as not to catch the wind (such as a bottle), and observed from a considerable height, will give the periodic time with a fair degree of accuracy, and the length may be inferred from the period.

General observations upon waves† are not in point. The object in the present case is to ascertain what the particular waves are in which the ship's rolling is being observed.

* See Mr. Rankine's remarks in the "Transactions of the Institution of Naval Architects," vol. iii., p. 27.

† Although very desirable for other reasons.

MEASUREMENT OF ROLLING.

It is very well known that a pendulum at sea does not give a vertical line, but a direction due to the joint effect of gravity, of its own free oscillation, and of the forced oscillation due to the motion of its point of suspension. A suspended clinometer is thus perfectly useless for this purpose. Barometers, cuddy lamps, and chandeliers generally oscillate through larger angles than the ship.

Mr. Froude ("Transactions of the Institution of Naval Architects" for 1862, p. 41) suggests watching the ratlins of the rigging come down to the horizon as a ready and fairly correct way of measuring the roll. The motion of the mast heads relatively to the stars, may be used in the same way.

M. Normand, Jr., of Havre, has invented a very ingenious clinometer suspended on gimbals, like a chronometer, in such a way as to be as little as possible influenced by the ship's motion.* We do not consider that any instrument depending upon gravitation is to be relied upon at sea, and we have been informed that M. Normand himself is not quite satisfied with his instrument.

Apart from observations depending upon the stars, or actual sea horizon, the only instrument that can be relied upon as giving an invariable plane is of the gyroscope class. A modification of Foucault's gyroscope was tried in the North Sea in 1859, by Professor C. Piazzi Smyth, who gave an account of the instrument and of its performance in the "Transactions of the Institution of Naval Architects" for 1863, p. 118.

An instrument upon the same rotatory principle, but self-recording, has been invented by Admiral Paris, Hydrographer of the French Imperial Navy. It consists of a spinning top, with its point of support above its centre of gravity. It spins in an agate cup, and the top of the spindle carries a camel's hair pencil, which marks a paper band, driven by clockwork, and passing through bent guides so as to keep close to the pencil. It is described, and some of its curves copied, in the "Transactions of the Institution of Naval Architects," vol. viii., for 1867.

What these instruments really give, is

* See "Transactions of the Institution of Naval Architects" for 1866, p. 187.

the deviation from an undetermined direction. They therefore give the time of rolling or pitching, and of any intermediate oscillation of a periodic character, and the amplitude of deviation from the mean line; but they evidently would not disclose any steady inclination to which the rolling might be superadded.

The gyroscope or top will, of course, have its own proper oscillatory revolution, which, however, soon spins out, on the same principle that a pegtop "sleeps."

On the whole, there does not seem to be much room for improvement in Admiral Paris's instrument, unless, perhaps, in diminishing the atmospheric resistance. Possibly, also, provision might be made for adjusting the point of support to the centre of gravity.

RECOMMENDATION OF EXPERIMENTS ON ROLLING.

The mathematical theory of rolling is very far from easy, and leads to equations of which there is no known solution. The time of a common pendulum, for instance, depends upon an elliptic integral, and, beyond the degree of complexity involved in such a junction, mathematics are in the condition of uncleared ground. Accordingly, while it is possible to give a rational account of the immediate gross results of a compound oscillation, these results cannot be expressed or measured with the requisite combination of generality and accuracy. In order to treat them we are obliged to introduce simplifying suppositions, which do not necessarily belong to our problem—as, for instance, isochronism—or, the neglect of certain elements of resistance, or the grouping of others.

Now, when this occurs with any branch of practical knowledge, the proper mode of applying mathematical investigation is to start, not from the known principles of general mechanics, but from an advanced base of observations peculiar to the science itself. In hydrodynamics, between minuteness and number, the ultimate molecular unit escapes our notice, and we are only able to observe effects in the gross; being thereby driven to a certain want of detail, both of observation and of reasoning, which allows us to trust our conclusions only when they have been made to rest on a broad experimental foundation. Whether we regard the theory of the propulsion of ships, or that of their rolling, our analysis has assuredly been pushed quite to the extreme verge to which general reasoning can be trusted; and a largely increased extent of exact observation ought to precede further attempts at inductive reasoning on these subjects. We have many exact experiments on propulsion, although from the complicated character of the phenomena involved, it is difficult to separate the issues; and this will probably not be set right without further special investigation. With regard to rolling, however, we have much vague observation, and but little exact knowledge derived from experiment.

We are not aware of any one published experiment on the rolling of ships in waves, in which the details necessary to make any mathematical use of the results are supplied. The data required are, as a minimum for each case:

1. A draught of the ship and her calculated elements.
2. The position of her centre of gravity.
3. Her periodic time in still water.
4. The condition of her wet surface.
5. The extent and period of her roll.
6. Was the rolling simple, or mixed with pitching?
7. The height, length, and period of the waves in which she was rolling.
8. Were these waves simple?
9. What alterations have been made in her displacement, her trim, and the position of her weights, as regards both centre of gravity and moment of inertia previously to the trial?
10. Force and direction of wind, and condition of ship as regards resistance to it.
11. Full details as to the manner in which, and the instruments or calculations by which, these data have been ascertained.

There is no doubt that for a comprehensive view of the subject, it would be necessary that these things should be ascertained with care for a large number of ships of various classes, and under very varied conditions. But this is too much to expect to get done, although we think it would be a good thing for the Government and other large shipowners to keep in view as an ultimate object. Meanwhile, we think it would be a very great experimental aid to science, if these things could be accurately settled for even two or three

ships, under different circumstances of weather, and different arrangements of weight, both in amount and distribution.

Similar experiments should also be made with reference to pitching.

The trials should be made with sails furled, and as little disturbance from headway as possible. We have every wish to have parallel experiments, tried under any possible conditions of sail and propulsion; and if it may be done, on the same ships, consecutively with the simpler experiments. But it will be seen that the data are already sufficiently complex at the best, and that they must be used clear of headway and leeway before they can be discussed with reference to these.

No experiments are of use for the purpose of inductive reasoning, in which any one of the data mentioned above is wanting.

We think the Government might fairly be asked to institute such a set of calculations and experiments. We cannot find that the exact information which we have suggested is in existence anywhere. We are certain that it has not been published in any available form; and we have reason to believe that the knowledge is quite as much needed and desired by the gentlemen responsible for the construction of the navy, as by merchant builders, or by students of theory.

We therefore recommend that the deputation previously mentioned with reference to the experiments on resistance, be also instructed to urge upon the Admiralty the importance, both practical and theoretical, of instituting such a set of experiments, of providing suitable instruments for recording exact observations, and of publishing the results. We also recommend the appointment by the Council of the Association, of a committee of *three* members, to confer with the officers of the Admiralty as to the drawing up of detailed instructions for conducting these experiments; and that the Lords of the Admiralty, in the event of their assenting to the proposals, be requested to nominate a committee named by the Association.

In conclusion, we beg leave to recommend that this report be officially communicated to the Councils of the Institution of Civil Engineers, the Institution of Civil Engineers, and the Institution of Engineers in Scotland, and the coöperation of those bodies sought, both in applying to the Government, and in making known among shipbuilders and other persons connected with naval architecture, as well what is the state of our existing knowledge, as what are the immediate desiderata for its extension.

An Earthquake-Proof Church. — The people of California, since the earthquakes of 1869, have a great deal of recurring shocks, and, as an indication of this wholesome fear and a desire to prevent loss of life, we have intelligence from San Francisco that the Roman Catholics are building there an "earthquake-proof church." This edifice–St. Patrick's Church —is built on a plan to prevent loss of life in the event of the shaking down of the walls. The side walls above the basement are only 30 ft. high. At this height, a roof rises, which, with the main roof, is supported independently of the walls by two rows of pillars inside of them. Both roofs are firmly bound to the pillars, and the pillars are fastened together by iron cross-beams, secured with heavy iron bolts, forming a network of great strength. The theory of the plan of construction is, that should the pillars be shaken down, the roof would be launched off outside the walls, instead of falling inside, thus giving a chance of escape from the ruins. In thus falling the roof would be carried aside a distance of 80 ft., the length of the pillars.—*Scientific Journal.*

The Mouth of the Mississippi.—The report submitted by the Engineer Department, on the work of deepening the passes from the Mississippi to the Gulf of Mexico, shows that Pass a l'Outre, the one selected for improvement, has been deepened from 11 to 17 ft., the channel being 175 ft. wide. The current, however, will soon reduce it to its former condition if the labor upon it is relaxed. The digging is done by a dredge-boat, constructed especially for the purpose, at a cost of about $300,000. In order to keep open two channels, the building of two more dredges is recommended, after which the annual cost of keeping the channels open would be about $200,000.—*The Engineering and Mining Journal.*

THE KING'S COLLEGE GIRDERS.

From "Engineering."

If any justification of this recurrence to the somewhat stale subject of the failure of the cast-iron girders crossing to the King's College dining hall is considered necessary, it will be found in the universally accepted engineer's axiom, that failure is more instructive than success. The lesson afforded by a failure, however, is entirely lost if a false deduction is allowed to pass current; and for that reason we consider it advisable to recapitulate some of the conclusions advanced in our pages immediately after the fall of the girders under consideration.

Our American cousins discuss the engineering questions arising in their fatherland on this side of the globe, with as lively a degree of personal interest as English engineers themselves. For their facts they are necessarily dependent upon our technical journals, and this condition should afford an additional incentive to exactness and thoughtfulness on the part of the framers of reports in those journals. Had this responsibility been properly appreciated by all of our architectural and engineering authorities, our Transatlantic contemporary, the "Scientific American," would not have perpetrated the anomaly of making the failure of a rotten cast-iron girder at King's College, the text of a leading article entitled, "Pumping Down Buildings."

It may, perhaps, be possible to "pump down" buildings founded upon certain special and treacherous geological formations; but it is certainly a catastrophe which has never befallen the dwellers in the valley of old Father Thames. Underground railways have tapped the gravel overlaying the London clay, in every direction, and for many miles. The trenches for these railways constituted in effect so many huge wells, the bottoms of which were sunk some 15 ft. to 20 ft. below the level at which the water stands in the surrounding gravel basin. To keep these trenches dry during the construction of the works, it was necessary to sink sumphs some 10 ft. deeper still, and from each of these numerous sumphs vast volumes of water, clear as from any spring, were ejected day and night by powerful pumps. All this has been done through the most thickly built city in the world, where ponderous and lofty buildings, in many instances old and shaky, extend to within 5 ft. of the edge of the trench, and in no single instance has any building been "pumped down," although some 20 ft. of the sand and gravel immediately under the foundations have been completely cleared of water.

We do hope, therefore, that we have heard the last of the King's College girders being "pumped down." Had there been any difficulty in making a correct diagnosis of the case, such an error would perhaps have been venial; but under the actual circumstances it is inexcusable. The true cause of the accident was clearly demonstrated in our first article on the subject ("Engineering," vol. viii., p. 393), which was written after a careful inspection of the broken girders. As some recent tests of the girders have exactly corroborated the deductions then made, we may usefully recapitulate our summing-up, which was as follows:

"The simple facts of the case are that the girders were carrying two-thirds of their calculated breaking weight, and probably would be carrying the same at the present time, had not the presence of some extensive flaws in one of the girders at a point 3 ft. from the support induced failure at that relatively little strained portion of the girder. The fall of one girder was of course followed by the destruction of the whole. We leave our architectural and building friends to draw their own conclusions."

We will now see if any additional light has been thrown upon the question by the results of the testing of one of the King's College girders, of slightly different dimensions to the original broken girder considered in our article. The calculated strength of the girder as there given, reduced to the equivalent breaking weight applied at the centre, is 32.2 tons at the span of 19 ft. Now the girder actually tested was 20 in. deep, whilst the one which first failed was but 18 in. If the girders were in other respects similar, this increase of $\frac{1}{9}$th in the depth would augment the transverse strength of the girder by the slightly increased fraction $\frac{1}{8}$th. But

the thickness of the bottom flange was $1\frac{3}{4}$ in. instead of $1\frac{5}{8}$ in.; consequently there would be due to the second girder a further increase of $\frac{1}{13}$th in the resistance. Again, the latter girder was tested at a span of 18 ft., whilst the actual span of the original girder was 19 ft., and the corresponding breaking weight at the centre would, of course, be greater in the inverse ratio of the span, which gives us another increment of $\frac{1}{18}$th. The calculated breaking weight at the centre of the girder actually tested, assuming the quality of metal to be the same as that taken in the instance of the girder referred to in our first article, would be greater, by the sum of the several fractions enumerated, or $\frac{4}{157}$ths. Now, $\frac{4}{157}$ths of 32.2 tons, the calculated breaking weight of the girder which caused the catastrophe at King's College, is equal to 8.3 tons; consequently, the ultimate load which the girder actually tested might have been expected to sustain would be 40.5 tons. As the girder failed under a stress of 40.9 tons, no demonstration is required to convince any one that the result of this recent experiment does not afford any information which was not confidently advanced by us in our article of the 10th of December last.

The fact that the girders over the dining-hall had, for the last thirty years, been subjected to a constant stress amounting to $\frac{2}{3}$ds of the breaking load, must now be considered as both theoretically and practically demonstrated. It will, therefore, be unnecessary again to open the question; and it only remains for us to congratulate the College authorities upon the opportuneness of the moment at which the accident occurred, and to express our earnest hope that we have heard the last of "pumping down buildings."

A NEW WATER METER.

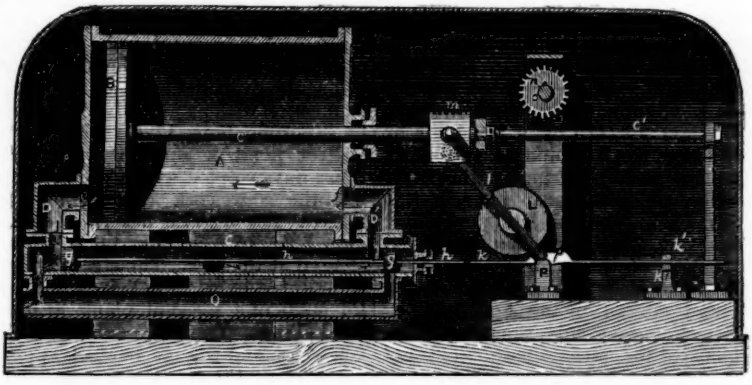
From "The Practical Mechanic's Journal."

This invention relates to a peculiar construction, arrangement, and combination of apparatus for measuring liquids and for registering the quantity measured, and consists in combining one or more horizontal cylinders of any known capacity provided with pistons and rods working through stuffing boxes with self-acting inlet and outlet valves and self-acting slide valve for directing the flow of the water to each end of the measuring cylinder or cylinders alternately. According to one arrangement the patentee fixes to the outer ends of the measuring cylinders a cylindrical valve case, having two lateral openings communicating through the end of the measuring cylinder with the interior thereof. In each of these valve cases work two piston valves, so disposed that, when one of the openings, say the inlet, is open to the cylinder, the other or outlet shall be closed, and *vice versa*. The spindles of these piston valves may be connected together by an oscillating beam or lever, which causes one pair of piston valves to descend when the other is ascending, the pressure of the water in the inlet pipe leading to the cylindrical valve cases alone serving to work the valves. In order to direct the flow of water into the opposite ends of the measuring cylinder or cylinders alternately, he adapts a suitable valve or valves to the inlet pipe or pipes, which valves he works by the aid of a weighted lever acted upon by a movable or fixed arm or projection at each stroke, so as to cause the weighted lever by its impulse to change suddenly the position of the slide or other valve or valves. The counting or registering mechanism may be worked by a pinion gearing into rack-teeth formed on the measuring piston-rod, or by any other suitable mechanical contrivance for transmitting motion from such rod. The whole is enclosed in a suitable framework or casing.

The engraving represents a longitudinal section of an arrangement wherein a single measuring cylinder only is employed in lieu of two, as in the first described arrangement. A is the measuring cylinder, B the piston working therein, and C the piston-rod provided with a cross head which slides along the guide rods C'. This rod C carries a rack *m* for actuating the counting mechanism through the pinion *n* on the spindle *o*.

This rod also carries a pendulous weighted lever I, having a bob weight L on its lower extremity, which actuates the

inlet valves in the manner hereinbefore explained; *e* and *f* are apertures made, one in each end of the measuring cylinder A, such apertures communicating respectively with the branch pipes D D', which communicate with the opposite ends respectively of the inlet pipe G. Other openings in this inlet pipe communicate with the outlet pipe O, and all these openings are alternately opened and closed as required, by the piston-valves *g g'* carried by the one-valve spindle *h*. To the outer end of this valve spindle there is attached a slotted frame *k*, guided in its longitudinal movement by the fixed guide *k'*; P is a fixed projection over which the lower end of the weighted lever I is drawn at each stroke of the piston B. In order to prevent the end of the lever I from leaving the slot in the piece K when elevated, by passing over the projection P, the slides of the slotted piece are raised slightly, as at *p*. The engraving represents the water as entering the cylinder A



from the inlet pipe G by the inlet aperture *f*, the valve *g'* being in such a position as to close the communication at that end with the outlet pipe O, whilst at the same time the water is being expelled from the opposite end of the cylinder through the aperture *e*, into the outlet pipe *o*, the valve *g* being in such a position as to bring the outlet pipe into direct communication with the interior of the measuring cylinder just before the piston completes its stroke in either direction; the tail of the weighted lever I slips off the projection P, and the weight L causes the lever to strike against one end or the other of the slotted piece *k*, thereby suddenly reversing the positions of the two valves *g g'*; when the operations above described are repeated, and the water is admitted to the reverse end of the measuring cylinder and soon, each alternate stroke being duly counted by the counting mechanism.

Brussels is advocated by the merchants of Berlin as a favorable place for an annual international exhibition.

In the manufacture of quicksilver bottles, a circular disc of wrought-iron is, by a stamping process, gradually brought into the shape of a cylinder, open at one end like a glass tumbler. It is then put upon the end of a steel pin or mandrel, and by mechanical pressure is pushed through a hole, which hole is smaller than its own dimension, thereby reducing its exterior diameter, and at the same time drawing, or rather pushing, the iron over the mandrel in the same manner as a piece of dough could be drawn over the finger to fit like a glove. This process is repeated through a succession of smaller and smaller holes, one after the other, until at length it becomes a long cylinder. The neck of the bottle is formed by a repeated pressing and twisting at the open end into a conical die, by which means it is gradually brought to the proper form. A screw is afterwards formed for the stopper by the ordinary means.—*Scientific Journal.*

The city of Rotterdam is to have a bridge over the river Meuse, 1,500 ft. long.

WHO INVENTED THE STEAMBOAT?

From "The Iron Age."

The question of who invented the steamboat could be correctly answered only by enumerating several projectors whose efforts succeeded each other during a period of three-fourths of a century. The propulsion of boats by paddle-wheels is said, indeed, to date back to the time of the Romans, but precisely in what way they applied the power is not known. As long ago as 1682 Prince Rupert, the courtly mechanician of the heyday of the Stuarts, propelled his barge in this way. In 1726, one Dr. Allen, printed a pamphlet in London, in which he proposed to urge a vessel forward by a jet of air or water ejected from a pipe at the stern. He thought that by using steam-power he could make 3 miles an hour in this way. In 1737, Jonathan Hulls published his invention, which may be considered the archetype of the modern steamboat. It had a paddle-wheel arranged at the stern, and worked by a steam-engine; but instead of the crank, the application of which to the steam-engine had not then been invented, Hulls employed a complicated set of devices for giving motion to the wheel. After this there was little or nothing suggested in the line of steam propulsion until 1782, when the Marquis de Jeoffroy tried a steamer on the river Loire in France. Instead of a paddle-wheel, he had the paddles arranged upon an endless belt that traversed 2 supporting pulleys, but the apparatus was not successful. Two years later, James Rumsey commenced experiments with a boat 80 ft. long, in which an engine worked a vertical pump that drew in water at the bow and ejected it at the stern. The reaction of the effluent water moved the vessel along at the rate of 4 miles an hour. This seems to have been a revival in some sort of Allen's plan; and substantially the same system has been frequently re-invented since, a recent and notable example of these jet propellers being found in the English vessel, the *Water Witch*. In 1786 John Fitch made public his project of moving vessels against wind and tide by fitting them with vibratory paddles worked by steam-power. There were 12 paddles, 6 on each side of the boat, one-half of those on either side working alternately with the other half of the number. The paddles were designed to have a stroke of 5½ ft., but it does not appear that the plan was ever subjected to actual trial. Fitch, however, did not rest contented with this plan, else he would never have been heard of afterward, but was also the inventor of a screw propeller, and also of the combination in one vessel of the screw and side-wheels—the principle of propulsion adopted in the *Great Eastern*. The screw-propeller, and mode of using it in connection with paddle-wheels, was shown by experiments in 1796, or 1797, on the Collect pond, a sheet of water that in those days rippled where the grim Egypt pile, the New York city "Tombs," now stands. The vessel is described as a common boat, 18 ft. long and 6 ft. wide, and steered at the bow. The steam boiler was constituted by a 12 gal. iron pot, with a lid made of a piece of plank firmly fastened down. The engine had 2 wooden cylinders, and the mechanical appliances for working the screw and paddle-wheels, although rude, were arranged with such effect that a speed of 6 miles an hour is said to have been obtained. The inventor, however, was too poor to continue his experiments, and too impatient of argument and contradiction to interest the incredulous moneyed men of the day in his enterprise. The boat, with a part of its machinery, was drawn up and left on the shore of the pond, and, piece by piece, this type of the future steam vessel fell to decay, and the children of the neighborhood gathered up its fragments and carried them home for kindling wood. A few years later, Fitch, a broken and embittered old man, with feeble health and ruined fortunes, poisoned himself with opium, and was buried in Bardstown, Ky. To this day no monument or headstone marks his resting place, but the fulfilment of his prophecies are shown wherever the steam-whistle sounds over the placid waters of rivers, or the turbulent foaming of the sea.

While Fitch and Rumsey were thus experimenting with steam propulsion, others were making trials in the same direction with more or less success. As an illus-

tration of the blunders that even truly great men will sometimes make, it may be noticed that about the year 1786, Dr. Franklin proposed to propel vessels by the direct action of steam upon the water, which was, of course, found to be utterly out of the question. About the same time, Oliver Evans advocated the employment of paddle-wheels, and a boat was run for a short time between Philadelphia and Bordentown, but no details of its means of propulsion have been handed down. In 1787, Mr. Patrick Miller, of Dalswinton, in Scotland, made a double vessel, moved by a paddle-wheel in the stern, and two years after constructed another 60 ft. long, that went at the rate of 7 miles an hour, but proved too weak to bear the action of the machinery. It is said that these experiments cost Miller upward of $150,000, for which he received no return whatever. A dozen years afterward, William Symington, who had made the steam-engines for Miller's boats, induced Lord Dundas to build a steam vessel for towing craft on the Forth and Clyde Canal. This, the *Charlotte Dundas*, dragged along 2 sloops of 70 tons burden each, against a strong head-wind, at a speed of 3½ miles an hour. The owners of the canal, however, refused to use this means of towing because of the liability of injuring the banks by the undulations of the water—the principal reason to this day why steam has not been applied in canal propulsion. From this time forward steam navigation began to assume a more promising aspect and more tangible shape. In 1804 John Stevens, of Hoboken, N. J., had a boat 24 ft. long fitted with a paddle-wheel at the stern, which, for short distances, made 8 miles an hour. The greatest benefit, however, conferred by Stevens upon the engineering world was in the invention of the tubular boiler—a principle of construction that has worked wonders in steam-generators for all purposes.

We now come to the efforts of Robert Fulton, a man who possessed business talent, and the faculty of mastering the details of whatever he undertook, in a no less degree than inventive skill. He left Philadelphia in 1786, and went to London, where, as early as 1793, he communicated with Earl Stanhope concerning steamboats—this nobleman being something of an enthusiast on the subject, and having a plan of his own, which has come to be known as that of the duck's-foot propeller. This was simply a kind of folding oar, which opened to act against the water when pushed outward, and closed when drawn back at the end of the stroke. After this, Fulton went to France, where he brought before Napoleon a method for blowing up the English ships; but, although he made an apparatus by which he was enabled to remain under water for a period of 4½ hours, he did not destroy a single vessel of the enemy. His journey to France, however, did him some good, for it was there that he became acquainted with Chancellor Livingston, who furnished the funds by which he was finally enabled to put his plans for steam propulsion into practice. Assisted by Livingston, he, in 1803, made experiments on the river Seine, with a paddle-wheel boat 60 ft. long. The results were so favorable that it was concluded to attempt without delay, the introduction of steam navigation on American waters. An engine was ordered from the English workshops of Boulton & Watt, and was duly forwarded to New York. In 1807 the *Clermont* was launched on the East River, and at once commenced running on the Hudson, between New York and Albany. Since then, until the present hour, there has not been a single day when vessels have not been propelled against wind and tide by the power of steam—the *Clermont*, having been, if not the earliest practical steam-boat, at least the first steam-vessel to establish a system of regular trips between different places.

Joseph Glynn, in his treatise on the power of water, gives a description of a turbine constructed by M. Fourneyron, at St. Blaise, in the Black Forest of Baden, about the year 1837, which worked under a head of 354 ft.; its diameter was 13 in., the face of the wheel, or depth of buckets, was .225, or less than a quarter of an inch; it made from 2,200 to 2,300 revolutions per minute. This turbine drove a cotton mill of 8,000 spindles with all the accessories.

A further improvement is contemplated in the streets of Paris, viz., the crossing of the streets through iron galleries, either above or below ground.

THE CORROSION OF SHIP-PLATES.

From "Engineering."

The application of steel to the construction of ships, which has of late years become one of the recognized channels of progress in marine engineering, has raised many questions, and has directed the attention of engineers and of steel-makers to many points of inquiry which were formerly considered of minor importance, and the investigation of which has been partly, if not entirely, neglected. The first argument in favor of steel, viz., the greater absolute strength, was of course so obvious as to admit of no discussion; but even on this head the question of "brittleness" was brought forward, and not until many thousands of tests and trials had proved the fact that steel, although of greater tenacity than iron, can be made of equal pliability and ductility as the softest iron, was this objection finally abandoned. But this was limited to the property of absolute tensile strength. The question remained open whether the resistance of steel plates to compression and to buckling is in equal proportion superior to that of wrought iron, as is the case with regard to the tensile strength. In this form the question was first raised in the columns of this paper by Mr. John Scott Russell, and a series of experiments conducted by Sir William Fairbairn, Mr. Kirkaldy, and others, have, in the course of the last few years, given satisfactory evidence upon this point. But there still remain some questions of another character, which are of equal importance as affecting the durability of the materials employed in shipbuilding. These refer to the chemical properties of the materials, viz., to their power of resisting corrosion when exposed to the action of the atmosphere, and to the still more powerful corrosive action of sea-water. It has been generally admitted that the action of diluted acids, and of sea-water, is more rapid upon steel than upon wrought iron; but a series of experiments made by Mr. Henry Bessemer some years ago, showed that there was an important point in favor of steel, viz., the uniform action of the chemicals upon the whole exposed surface of the steel plate, as compared with the irregular local corrosion concentrated upon certain places of the iron plate. Mr. Bessemer immersed pieces of steel plates and of iron plates in vessels which were filled with diluted acids, and with solutions of different salts. From time to time the plates were removed and examined. The action of the chemicals upon the iron and steel was strikingly different. The steel plate showed an uniform, close-grained texture all over its surface, and under the microscope the steel surface appeared of a homogeneous, crystalline structure. In the case of the iron plate, on the other hand, the chemical action had made more rapid progress at all the minute fissures and openings which represent the welds or the interposed layers of oxides or slags existing between the individual crystals of the wrought iron; and the appearance even to the naked eye showed that peculiar irregularity of surface which is frequently produced upon iron in the process of etching or "damascening." The microscope still further disclosed that the wrought-iron surface was furrowed to a greater, or less depth in certain places, upon which the chemical action seemed to have concentrated its effect, and which therefore formed points of weakness, the existence of which in a plate would be far more dangerous than the corrosion of steel, which spreads equally over the whole surface. Mr. Bessemer's experiments, however, did not touch upon the relative quantity of the corrosive action upon iron and steel. Upon this point some very interesting experiments have been recently carried out in France at the works of the Terrenoire Company, near St. Etienne. The Terrenoire Company are well known as the first makers of Bessemer steel plates in France, and in consequence of this position the managers of the Terrenoire Works had more than an ordinary interest in trying to establish, by direct experiment, the relative quantities of the corrosive action upon iron plates and steel plates which is effected by sea-water. These experiments were made under the direction of M. A. Jullien, the managing director of the company, by M. Jules Euverte, the manager, and M. Paul Lemonnier, assistant manager of the works. Samples of plates

were cut to exactly similar dimensions, and carefully weighed. These samples were plates of best wrought iron, of hard Bessemer steel, and of the softest kinds of Bessemer steel, particularly those qualities which are made at Terrenoire for boiler plates, without spiegeleisen, by means of Mr. Henderson's well-known alloy of ferromanganese. These samples were immersed in sea-water, and the effect of the chemical action was put to an immediate quantitative test by means of a galvanometer. The plate was connected with one of the galvanometer wires, and the other, which carried a piece of platinum at the end, was immersed in the sea-water without touching the steel plate. This established a complete galvanic battery, of which the plate under test was the only variable element (since the same galvanometer and the same platinum piece was applied to each test plate). The amount of electric force which was measurable by the galvanometer was therefore in direct proportion to the quantity of chemical action which took place between the sea-water and the plate, and the indication of the galvanometer gave therefore the exact proportionate amount of corrosive effect produced by the sea-water upon each of the plates. The experiments at Terrenoire have confirmed the fact that the corrosion of steel containing more than ½ per cent. of carbon is more intense than that of wrought-iron, but the corrosion of the softest kinds of steel containing from ½ per cent of carbon downward is *less* than that of wrought-iron. In fact the amount of corrosion of different kinds of steel seems to follow the exact proportion of the percentage of carbon contained in the metal. The relative quantities as read off the galvanometer when some of the most characteristic specimens were under test were as follows :

Corrosion of steel containing 1 per cent. carbon	80.
Corrosion of wrought-iron plate	65.
Corrosion of soft Bessemer steel plate	55.

The evidence of these galvanometric tests has been still further corroborated by keeping the different plates immersed in sea-water for several months, and ascertaining the loss of weight of the plates regularly every week. The result of this prolonged experiment showed an exact coincidence of the proportionate weights with those indicated by the galvanometer. The regularity is so great that the same galvanometer always indicates the same figures when applied to the plate after a considerable lapse of time.

The experiments of the Terrenoire Works show in a very conclusive manner that soft steel plates, such as are usually —and ought to be always—employed in ship-building, are *less* liable to suffer from the corrosive action of the sea-water than iron plates. The advantage of the steel plates previously pointed out by Mr. Bessemer is, therefore, still further enhanced by this newly discovered superior resistance to corrosion, which is a property of the softest kinds of steel.

Observations on Sound in the Lake Tunnel at Chicago.—The Eighth Annual Report of the Board of Public Works, of the city of Chicago, in giving a history of the lake tunnel, says that observations on sound were frequently made during the progress of the work. The first distinct notice of anything of this kind was when the tunnel had been made 100 yards from the land shaft. Just above the tunnel is the breakwater inclosing the inlet basin. The outside of the breakwater consists of round piles, laced from 1 to 2 ft. apart. The waves could be distinctly heard in the tunnel below, striking those piles through 60 ft. of earth. The next observation was the passing of propellers and tugs, when the tunnel reached half a mile or more out. The different noises made by a vessel or engine passing overhead could be heard as distinctly through 30 to 40 ft. of earth as on the surface of the water. It was considered a matter of much interest to determine how far sound could be heard through the clay. The miners thought it could not be more than 150 to 200 ft. In order to be certain, observations were made when the faces were 800 ft. apart, and sounds of blows of iron on stone or iron in the clay, but not on the clay itself, could be heard with great distinctness. Whether the sounds passed through 800 ft. of clay, or first through 30 ft. of clay, then through 800 ft. of water and then through 30 ft. of clay, is a question—probably the latter.

There are no fewer than 241 Hindoo temples and Mohammedan mosques in Calcutta alone.

THE COAL FIELDS OF THE NORTH PACIFIC.

From "The Mining Journal."

The coal supply, no matter whence that supply is derived, is a subject in which every one is interested, and accounts of new fields, or those with which we are but imperfectly acquainted, are particularly acceptable. For this reason the paper "On the Geographical Distribution and Physical Caracteristics of the Coal Fields of the North Pacific Coast," read before the Edinburgh Geological Society, fairly claims favorable mention. The position of the author, Mr. Robert Brown, F. R. G. S., as commander and Government agent of the first Vancouver exploring expedition, is a sufficient guarantee for the value of his opinion. He explains that extending from California to the borders of Alaska are three coal fields, belonging respectively to the Tertiary, Secondary, and Palæozoic ages, the latter being situated, as far as yet known, only in the Queen Charlotte Islands, off the northern coast of British Columbia, the exact age being as yet undetermined, though the coal is anthracite, and is, in all probability, Palæozoic. The other two coal fields are situated, as regards each other, from south to north, in the order of their age. The Tertiary extends from California northward, and through Oregon and Washington Territory, impinging on the southern end of Vancouver Island and British Columbia, and extending, with some interruptions, right across the Rocky Mountains, the Miocene coals of Missouri being apparently only a continuation of these same beds. The secondary beds, on the other hand, on the North Pacific coast, are confined to the Island of Vancouver, though in all probability they are also a continuation of the cretaceous strata of Missouri.

With regard to the Tertiary coals of the North Pacific, Mr. Brown states that the lignitic beds are associated with shales and sandstones alternately, and the contained fossils show it to be of Miocene age throughout. The coal from it is of a very uniform character, burning freely, but leaving behind much slag and ash; and in many cases, though giving out a strong heat, unsuitable for domestic purposes, on account of its sulphurous character. It has, however, been wrought at various places thoughout its extent, and is at present being mined for commercial purposes at several localities—Monte Diabolo, California; Coose Bay, Oregon; Clallam Bay, opposite Vancouver Island; Bellingham Bay, and elsewhere. Regarding the quality of the coal it is difficult to form an estimate, from the often very partial reports of interested parties. It is, however, said that the clean picked coal gives very little ash, burns with a clear bright flame, and gives out considerable heat. Some of the large lumps contain veins of sand-stone, varying from ½ to 1½ in., and to this possibly may be attributed the great amount of "clinker" which it forms on the furnace bars. It is only just to say that all hitherto tried for steaming purposes has been merely surface coal, and, therefore, of inferior quality. The coal itself is hard, giving a brown lignite-like appearance on being scratched, shining equal to the appearance of anthracite, and breaking in small cubical fragments.

The valley between Olympia and the Columbia river, generally known as the Cowlitz Portage, appears to be a coal basin to some extent. Coal has been found not far from the celebrated Mound Prairie, about half-way over, and on the Monticello and Columbia rivers, but in such small quantities as hitherto to have rendered it unworthy of being wrought. If coal could be found in proximity to the splendid but undeveloped iron mines of the Columbia, the result would be of great commercial importance. Near the Squak prairie, 25 miles from the village of Seattle, coal is seen to crop out on the side of the mountain in seams of 2 or 3 ft. in thickness, but as its position would render its transportation expensive, it creates but little interest. On the Stoluchwamish river, north-east of Seattle, a thin seam of coal has been found, but is not wrought. It is only when we arrive at Bellingham Bay, situated a few miles south of the British boundary line (latitude 49 deg. north) that we find the coal of sufficient thickness and proximity to the sea to render it of sufficient importance to be mined. Here a company have been at work for a number of years, and

export a considerable amount of coal to the San Francisco market. It is of the same quality as the other tertiary coals of the coast, and is generally mixed with a better class of coals before being used. The mines are very full of fire-damp, while the various mines of cretaceous age are entirely free from this.

The whole coast of Vancouver Island, on the east coast, north of Chemainos, and round to Koskeemo Sound, on the westward, and for some distance into the interior, is bounded by a belt of carboniferous strata, composed of sandstones, shales, and coarse gravel-stone conglomerates, interstratified with which are beds of coal of much superior character to any hitherto described. These beds, from the fossils they contain, appear to be cretaceous. Everywhere the strata named form a characteristic accompaniment of the coal, especially the coarse conglomerate just named; and nearly everywhere it is underlaid by one or more seams of coal. Hitherto we have only found it cropping out at some points of the circuit named, though it may reasonably be supposed yet to be found on the opposite shores of British Columbia. The wall of the deep fiords indenting this part of the coast everywhere are, however, in most cases composed of trap and other igneous rocks, and whatever sedimentary rocks may at one time have reposed on their flanks have now been washed off by the action of denudation.

The Nanaimo coal is bright, tolerably hard, and not unlike some of the best qualities of English or Welsh coal in appearance. It burns freely, with a good heat, but produces a great amount of ash. It is universally used by all Her Majesty's ships on the coast, and by all of the colonial and other steamers plying on the coast. It is highly valued as fuel for domestic purposes, both in Victoria, San Francisco, and other towns. Gas is manufactured from it at Victoria of good illuminating quality. No fire-damp has hitherto been found in the mine. The coal is easily wrought, a miner being able, under favorable circumstances, to take out about 2½ tons in his working time, which, at the rate of 5s. per ton for his clean dressed coal, will net him about 11s. per diem. Most of the miners are from Scotland or Lancashire, and generally employ an Indian to clean their coal for them. They rarely work a full day, preferring to earn a constant moderate wages rather than run the chance of getting the price lowered by their producing the coal in greater quantities.

North of Vancouver Island, at a distance of from 20 to 40 miles from land, lie the Queen Charlotte Islands, consisting of a group of three main islands, with a number of lesser islets lying off the shore. These islands are, in general, densely covered with forest, and permeated by inlets of the sea; but their interior is entirely unexplored. They are, however, rich in copper and other minerals; and gold quartz, of a surprisingly rich description, was discovered in one spot here about 15 years ago. A hot spring is found at the southern end of the most southerly island; but there is no volcano here, as Mr. Mallet erroneously places on his map of earthquake phenomena and volcanoes. The island, though so near the mainland, differs remarkably in having no deer, wolves, or raccoons—animals extremely abundant on the opposite shores of British Columbia. The coasts are inhabited by several tribes of a very fine-looking, stalwart, and warlike race, generally known under the name of Hydahs. There are no white settlements on these islands, but they are occasionally visited by well-armed traders, for the natives bear the reputation of being anything but a remarkably docile race, a reputation earned by many lawless and cruel acts.

Of late years coal has been discovered on these islands of a very superior quality. Accordingly, in the spring of 1866 I took advantage of a party of miners going up to "prospect" this coal to pay a visit to the islands. I saw no appearance of coal—or, indeed, of any sedimentary rock—along the whole coast of British Columbia until we arrived at these islands. Here the coal crops out in various places on the islands, but its chief development is at Skidgate Bay, where I passed some weeks. The whole of the beds seem to have been thrown out of position by erupted masses of felspathic trap, on the flanks of which the beds reposed, and by which the strata (sandstone, etc.) have been much metamorphosed, and the coal altered. Two rival parties of miners were there prospecting, and one of them had driven an adit into the hill side some 200 or 300 ft. above the sea level. Here they had

gone through a great bed of coarse conglomerate—a fine hard slate—when the coal was reached. This conglomerate was in every respect similar to that associated with the Nanaimo coal fields, but the slate was peculiar. It is a close-grained, lustreless material, breaking in cuboidal fragments, and easily wrought. The coal was apparently of the nature of a true anthracite, with a bright lustre, hard, and giving out an intense heat. Recent efforts have been more satisfactory than the earlier ones, but Mr. Brown thinks that the working of the coal will always be difficult, on account of the numerous faults, dykes, and other disturbances.

SOME DIFFICULTIES IN THE RECEIVED VIEWS OF FLUID FRICTION.

By MR. W. FROUDE.*

From "The Engineer."

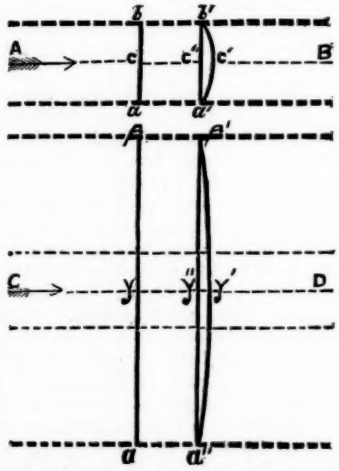
The very great variations in the resistance offered to the flow of water through the main of the Torquay water supply, arising from apparently small variations in the roughness of the interior surface, have led me to think that our views of the character of that action which is commonly termed "fluid friction," or "skin resistance," requires further investigation, and perhaps material revision.

The accredited laws which are held to govern the resistance arising from this action are based on the following considerations: (1) That the resistance offered by each square foot of rubbing surface in a given plane moving edgewise, is the same throughout the plane; (2) That it is as the square of the velocity of the surface through the surrounding fluid, or of the surrounding fluid past the surface. And this relation is usually expressed by a simple coefficient, the value of which is known to vary somewhat with the quality of the surface, being increased by its roughness, and is held to be somewhat less for high velocities than for low.

If we express the friction by $f = k\, v^2\, a$, (v) being the velocity in feet per second, and (a) the friction bearing area in square feet, the value of (k) as deduced from Beaufoy's experiments with a smooth painted plank moving through open water, is 0.0034, while Professor Rankine takes it at about the same value, or 0.0036 for clean painted iron. And as deduced from Professor Rankine's rules for the flow of water through pipes of cast-iron, its value appears to vary between 0.0092 for velocities of about 1 ft. per second, and 0.0056 for velocities of about 4 ft. per second.

The excess which is observed in comparing the coefficient of resistance suitable for the internal surface of a pipe, with that suitable for smooth surfaces in open water, represents the circumstances that the central or maximum velocity of the contents of a pipe considerably exceeds their mean velocity; and that a cast-iron surface—that commonly referred to in pipes—is probably inferior in smoothness to a painted surface, while the excess in the coefficient appropriated to the higher velocity, represents the probability that the imperfect fluidity of water is more felt when the velocity is small.

Fig. 1.



The *rationale*, if I may use the term, by which the flow of water through a pipe is deduced from this coefficient of friction, and the internal area of the pipe, involves the assumption that one and the same

* British Association.

multiple of the mean velocity, is equally applicable to all pipes of whatever diameter, as the effective velocity in virtue of which the coefficient is to be applied.

This assumption will now determine the resistance which each length-unit of pipe, of given diameter, will offer in virtue of the velocity of flow; and if the mean declivity, or hydraulic gradient, be also given, the velocity must be such that this resistance shall exactly balance the force which the weight of the corresponding length-unit of internal water column exerts along the pipe in virtue of the gradient.

The usual formulæ are thus deduced, which give the mean velocity as proportioned to the square root of the diameter and the square root of the gradient, and the delivery per minute as proportioned to the power $\frac{5}{2}$ of the diameter and the square root of the fall.

This mode of viewing the question does not essentially differ from that of supposing the enclosed column of water to glide bodily along the interior of the pipe, and the resistance to be delivered at a definite rubbing surface as with solid friction, depending, however, not on pressure of contact, but on velocity of gliding. And the supposition seems to lead to some irreconcilable consequences.

The character of the motion involved in it may be geometrically represented as follows:

Let A B, Fig. 1, be a portion of pipe having a diameter = unity, and let the water within it be flowing in obedience to some given hydraulic gradient, and therefore with some definite mean and effective velocities, say V and V'.

Let *a c b* be the line occupied at any moment by a series of diametrically placed particles; then the supposition which we are examining will be represented by assigning to these particles, after the lapse of a definite unit of time, some new position, *a' c' b'*, in which *a a'* and *b b'* will represent the effective velocity, and the ordinates of the curvilinear area *a' c' b' c''* will represent the excess of the mean over the effective velocity, or (V − V').

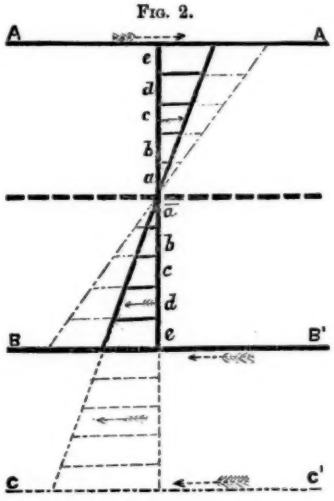
Let us now compare with this the state of things which, on the same supposition, will similarly ensue in a pipe of larger, say quadrupled diameter, under the same hydraulic gradient, and let this pipe be represented by C D.

In this case, since by the formula the velocity is as the square root of the diameter, the effective and the mean velocities will alike be doubled; and a series of displacements throughout, equal to those which take place during the unit of time in the small pipe, will take place during half that unit in the larger pipe.

Forming a diagram on this basis, we shall have $a'\ a' = a'\ a'$, and so on throughout.

Now, it appears to me difficult to believe that the particles along the line

Fig. 2.



a' β' γ', which has a quadrupled length, and therefore presumably a greater mobility, in the larger pipe, will not be bent forward in the middle through a wider space than the particles along *a' c' b'* have been bent forward in the smaller pipe, which are all so much nearer to the restraining surface. Or to place the difficulty in a more definite shape, if we mentally picture to ourselves within the larger tube the conditions of a central column of water having the same diameter as the smaller tube, as indicated by the dotted lines, I do not see why we ought not to expect that central column to glide forward as rapidly past the moving particles which immediately surround it, as the similarly placed particles in the smaller tube glide forward within the fixed sur-

face of the tube; unless it be more difficult for particles of fluid to slide past one another, than for them to slide past a fixed surface.

Viewing the matter in this light, I am led to the conclusion that there is no real justification for the idea of discontinuity in the velocity where the water meets the surface, and that the "state of motion" must really consist of a graduated series of velocities increasing from the circumference to the centre, annulus sliding within annulus, and the resisting force being a function, not of some arbitrarily assumed effective absolute velocity, but of the relative velocities of contiguous particles.

This crude suggestion may be framed into a more intelligible hypothesis, if embodied in a diagram which presents it under a somewhat different aspect.

Let A A′, B B′, Fig. 2, be two planes of infinite extension, guided so as to move edgewise parallel to one another, and moving with equal uniform velocities in opposite directions, the intervening space being filled with water.

Then when the state of intervening motions and forces has become established, there are several consequences of the supposition which may at once be regarded as certain.

In the first place, each plane will experience a definite resistance per square foot the same throughout along its line of action, and the same for both; and these equal and opposing forces must be somehow transmitted from the one plane to the other, square foot by square foot, through the intervening water, maintaining in it a definite constant state of motion.

In the next place, the particles in absolute contact with each plane, will be moving with the velocity of the plane.

Further, the line of particles midway between the planes must be stationary, since it is symmetrically situated with reference to the two equal and opposing motions and forces.

And lastly, any intervening particle on either side of the central line must be moving with some graduated velocity, accordant with that of the plane to which it is nearest.

Now, if the planes be so free from roughness as to be incapable of imparting lateral impulse to the water, it seems clear that the growth of velocity on either side of the central line must be uniform, as we recede from the centre. For if we imagine the intervening fluid as consisting of successive parallel layers of equal thickness, each layer must be so moving past the contiguous layer, as to transmit to it, square foot by square foot, that identical force which is experienced as resistance by the boundary planes. And it would seem that therefore layer *a* must be passing layer *b* as fast as layer *b* is passing layer *a*, and so on throughout.

The ordinates of the triangular spaces shown on either side of the centre, will thus represent the respective velocities of the corresponding particles.

If this view be sound, it follows that, were we to establish a third plane B B′, making the distance B C (say) = ½ A B, and were we to assign to this plane a conformable velocity double that of the plane C C′, and let the intervening space be filled with fluid, carrying on the same established growth of velocity as before, in a continued series to the outer plane, we should, under these circumstances, transmit to that outer plane exactly the same force per square foot as that experienced on the original planes; and the plane B B′ would meanwhile assume merely the condition of one of the intervening layers of fluid, becoming a mere neutral instrument in the transmission of force and motion.

We should thus have, on the plane C C′, moving with an absolutely double velocity, only the same velocity relatively to the contiguous water, and only the same force per square foot, as on the plane A A, moving with the single velocity.

Thus it would seem that the so-called force of friction may be more properly regarded rather as "resistance to deformation" than as "friction," in the usual sense of the term; and that its measure depends, not on the absolute velocity of the moving solid surface which initiates the deformation, but on the rate at which the deformation is transmitted from layer to layer.

Thus, though the double velocity of the plane C C subjects it to no enhanced resistance, since the rate of transmitted deformation is in that case unchanged, yet if we had doubled the velocities of the two original planes A A′, B B′, we *should* have enhanced the rate of transmitted deformation, and in some degree, as yet unknown,

we should have also enhanced the resistance.

We thus have to regard the resistance as governed by what we may term the "angle of deformation," say (ϕ), which might be defined as the change of angular position which, in a given infinitesimal unit of time, the relative motions of two closely contiguous particles impose on a line which at the commencement of the interval was at right angles to the line of motion, thus expressing the space by which, during the assumed interval of time $d\,t$, any particle in the line E E, Fig. 3, is carried past its opposite particle in D D, in terms of the interval between the lines. The resistance will probably be some function of (φ).

In the case of the infinitely extended parallel planes just now considered, (ϕ) was constant throughout the whole intervening space. But in the case where a plane is being intruded into a volume of stationary particles, (ϕ) will be found to vary in terms of (h), the lateral distance between the particles concerned and the plane, as well as in terms of (s), the distance along the plane. And at any distance along the plane $\left(\frac{d\,\phi}{d\,h}\right)$ will contain a measure of the varying force which penetrates the surrounding fluid, so far as this has become affected by the motion, and will thus also contain a measure of the accelerating force which actuates the intervening layer; because it expresses how much greater force is dragging the layer forward on one face, than is dragging it backward on the other. This state of things is represented in Fig. 4.

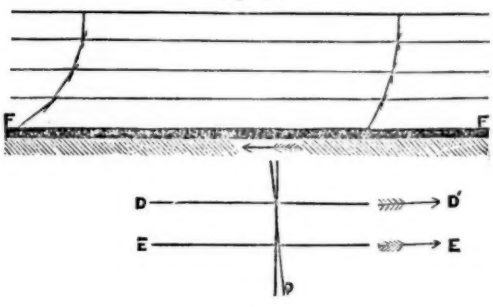
From this mode of viewing the subject, it would follow that when a plane of considerable length is moving edgewise through undisturbed water, a square foot of surface at its head-end must experience a greater resistance than one near its stern-end, because the force exerted by the head-end has already imposed force and motion on the particles which flow past it, and the state of motion must have spread into the surrounding fluid, so that at the stern-end the valves of (ϕ) and of $\left(\frac{d\,\phi}{d\,h}\right)$ will both be less than at the head-end.

Were the law of force in terms of (ϕ) known, it would be possible to construct a differential equation which would show the rate of accumulation of the current along the side of the plane, and its penetration into the surrounding fluid.

That some such correction of the usual views on the subject is required, appears to me to be inevitably involved in the fact that the growing current I refer to, visibly as well as necessarily exists.

It seems a paradox to say that the stern-end can experience as much force per sq. ft. as the head-end, when there exists a favorable current of considerable velocity and of considerable thickness alongside the former, which has no existence alongside the latter. It is equivalent to saying that were we to plunge a plane edgewise into this favoring current it would experience as much resistance as if we plunged it into the as yet undisturbed water outside the current.

Fig. 3.



I may add that of all the conditions affecting the resistance of a ship, this alone seems to me to perplex the comparison between the resistance of a ship and of a model similar to the ship; but it must equally perplex the comparison between the resistance of similar ships of different sizes; and the law which governs the condition will be readily determinable by experiment.

The state of the works on Mont Cenis Tunnel, Jan. 1, was as follows: From the south, 20,510 ft. had been executed, and from the north, 14,953½ ft., making a total of 35,463½ ft., and leaving 4,914 ft. to be accomplished.

THE LOUISVILLE BRIDGE.

Abstract from "The Louisville Commercial."

The importance of this enterprise will be better recognized when it is known that it connects three great distinct systems of railroad. 1st. Being nearly on the direct lines between Pensacola and Mobile and Chicago, it completes the directly middle and South lines. 2d. It joins the missing connection of Memphis, New Orleans and the Lower Mississippi Valley and Texas with New York, Philadelphia, Baltimore, Washington, and the Northeastern States, thus joining a continuous line of railroad from the Southwest to the Northeast. 3d. It furnishes the best link in the chain of roads connecting Savannah, Charleston, Wilmington, Norfolk, and the principal cities of the Southern States, with St. Louis, Quincy, Burlington, Rock Island, and the lines starting from various points on the upper lines and rivers, and penetrating the far West to the Pacific Railway.

Louisville is the central point in the line of the unbroken rail routes between the Southeast and Northwest. Probably at no other point on the continent would the erection of a bridge furnish such facilities for travel and commerce. The importance of this route, socially and commercially, cannot be overrated, but might be reverted to at length. By it people are brought into more frequent and advantageous contact, heretofore separated by the river, and subject to the slow and uncertain movements of ferries, which at times, during the low water of summer, are either obliged to suspend altogether their trips, or make them at such lengthened intervals as to render it insufferable for any person to whom time is of any importance, to endure them, and which for a week at a time during the winter season have been obliged to tie up for fear of ice.

By these, as would have been thought a few years ago insurmountable obstacles, the cities of Louisville, New Albany, and Jeffersonville, have been separated.

Bridge engineers, fortunately, have for the last ten years been rapidly developing the science of bridging over large streams, and during the past three years two members of the profession have, by their genius, energy, and perseverance, overcome all obstacles, and erected this crowning monument to engineering skill.

LOCATION OF THE BRIDGE.

Previous to the organization of the company during the fall of 1866, preliminary surveys were made of the several crossings at Jeffersonville, Elm Tree Garden, and New Albany, with the view of ascertaining the best location for the proposed bridge, and its connection with the Louisville and Nashville Railroad and Jeffersonville and Indianapolis Railroad.

Early in April, Mr. F. W. Vaughan, assistant engineer, commenced the surveys for the final location, and made a series of observations to determine the direction of the currents at the various stages of the river. On the 15th of June a report was submitted to the Board, and the final location of the bridge determined. The location may be described as follows:

The track connecting the Louisville and Nashville Railroad with the bridge leaves the yard of that railroad north of the engine house near Tenth street. Entering Maple street, it passes to Fourteenth street, and thence to Portland avenue. From the avenue the track crosses to High street, in a prolongation line of Fourteenth street, then curving to the right, crosses the river at right angles to the direction of the currents, striking the Indiana shore at a point 1,500 ft. below Smith & Smyser's mill; from thence the line continues in the same direction in which it crossed the river until it reaches the dirt road between New Albany and Jeffersonville, where it commences to curve to the right, entering Ninth street in Jeffersonville, through which it continues to the connecting link with the Jeffersonville Railroad. The total length of the connecting link between the Louisville and Nashville Railroad and Jeffersonville Railroad is 3 miles and 7-10.

GRADES.

The grade of the track approaching the bridge on the Kentucky side corresponds with that of High street at the point where the crossing is made; from this point it ascends at the rate of 76 ft. per mile,

striking the first span of the bridge at an elevation of 63 ft. above low-water, and continues at the same rate until pier No. 13, on the south side of the middle channel, is reached, at a distance of 2,500 ft. from High street, and 2,196 ft. from the face of the southern abutment. Here the grade has an elevation above low-water of 95 ft. From here the grade is level for a distance of 2,243 ft., till pier No. 21 is reached, on the north side of the Indiana channel. The elevation above low-water in this channel is 101½ ft. (the low water-mark being 6½ ft. lower than in the middle channel), and from here the grade descends at the rate of 70 ft. per mile, reaching the southern abutment at a distance of 790 ft. from pier No. 21. and at an elevation of 35 ft. above the natural surface of the ground. The grade of the Indiana approach continues to descend at the same rate, reaching the surface of the ground 2,500 ft. from the abutment. This approach consists of an earth embankment.

ARRANGEMENT OF SPANS.

The superstructure is placed below the grade of track, except over the middle and Indiana channels. The lowest point of the superstructure at the middle channel is 90 ft. above low-water mark, and over the Indiana channel 96½ ft.

The length of each span, counting from the Kentucky to the Indiana shore, and the entire length of the superstructure, including abutments, will be seen from the following table, the length of the spans are from centre to centre of piers :

LENGTH OF THE SUPERSTRUCTURE.

	Feet.
Kentucky abutment	35.0
Two spans of 50 ft. each	100.0
One pivot draw of 264 ft. over canal	264.0
Four spans of 149.6 ft.	598.4
Two spans of 180.0 ft.	360.0
Two spans of 210.0 ft.	420.0
Two spans of 227.0 ft.	454.0
One span of 370.0 ft.	370.0
Six spans of 245.5 ft.	1,473.0
One span of 400.0 ft.	400.0
Three spans of 180 ft.	540.0
One span of 149.6 ft.	149.6
One span of 100.0 ft.	100.0
Indiana abutment	35.0
Total	5,299.0

THE FIRST STONE LAID.

On the 1st day of August the first stone was pronounced "well and truly set" in pier No. 10, by Mr. Hamilton, President of the Bridge Company.

The masonry was carried on in view of building the piers next to the Kentucky shore high enough to make their completion practicable during the high stages of water incident to the spring months, so that the erection of the superstructure could be commenced at the earliest possible moment. This point secured, it was determined to take advantage of the unusual low water, by putting in the most difficult foundations in the rapid water of the falls. This attempt was successful, three of the most difficult foundations being secured between the 1st of October and the 1st of December, and had it not been for an unexpected rise in the river, which carried away part of the temporary trestle and the coffer dam of the fourth pier, all the foundations on the rapids would have been secured.

Of the 27 piers, there were 17 started, from 1 to 14 inclusive, and 18, 19 and 20; of the remaining, 2 only presented difficulties. A suspension of laying the stone took place during the winter months, but the contractors improved the time in quarrying and cutting a large quantity of stone to be used when spring opened.

MASONRY CONSTRUCTION TRANSFERRED TO THE COMPANY.

During the first part of the season of 1868, the work was carried on as usual by contractors, but being conducted so slowly, the company became dissatisfied and took the contract from their hands, and on the 1st of September satisfactory arrangements were made to transfer the construction of the masonry to the Bridge Company. In accordance with this arrangement the contractors turned over to the company all the tools and appliances used on the work.

Soon after the transfer took place, an unusual rise in the river washed away all the building derricks, the temporary track for transporting stone for the piers, and caused much other damage. On the 1st of October not a derrick remained standing in the river. This state of affairs called forth the energy of the engineers, and they were equal to the task before them, for in three weeks a new track was constructed across the river, derricks and derrick boats built, and the work progressed simultaneously on ten piers.

An attempt was now made to secure the foundation for Pier No. 17, but, owing to unexpected difficulties, the lateness of the season, and a sudden rise in the river, it was abandoned. The foundation of Pier No. 21 was secured, after surmounting great difficulties, as well as those of all the remaining piers, so that at the close of the season of 1868, 16 piers were entirely completed, and of the remaining 11 all were started, excepting No. 17.

The laying of stone was suspended December 20, 1868, and resumed in March, 1869. For 4 months the stage of water in the river enabled the company to supply the material by barges.

COMPLETION OF THE MASONRY.

The water falling in its summer stage in July, a temporary track was constructed for supplying the piers with stone, and on the 24th of November, 1869, the last stone was laid in Pier No. 19.

The masonry consists of two abutments and twenty-seven piers, comprising, in the aggregate, 30,500 cubic yards of lime-stone each, which, for beauty and excellence, both in construction and material, is believed to be unsurpassed. The piers vary in height from 60 to 105 ft., and are laid in hydraulic cement, manufactured in the vicinity of Louisville. These huge piers rest on the solid rock bed on the river, the foundations of some of which have been secured with great difficulty, on account of the immense body of water rushing over them, and the tendency of springs to break forth in the coffer dams.

From the time of the transfer of the masonry contract to the company, until the completion of the work, it has been under the personal superintendence of Mr. Vaughan. Mr. Flannery remained on the work several months after the withdrawal of his firm, as superintendent of masonry, and, upon being called to a more profitable field of labor, was succeeded by Mr. M. J. O'Connor, who remained till the completion of the masonry. To these gentlemen is due great praise for the faithful, energetic and skilful manner in which they performed the difficult duties imposed upon them by their respective positions.

SUPERSTRUCTURE OF THE BRIDGE.

With the exception of the portion spanning the channels, all of the superstructure is placed below the grade of the road. The below grade or deck portion is constructed of Fink's Suspension Truss. The spans over the channels are constructed after plans arranged specially for this work. The whole superstructure is of iron (except the flooring) and consists of 27 spans, varying in length from 50 to 400 ft., the channel spans being 370 and 400 ft. in length, and no larger work has ever been constructed on this continent.

The superstructure, with a few exceptions, is built entirely of wrought-iron. The chords and brace shoes in the long spans, and the chords and post shoes in the suspension trusses, are of cast-iron. Throughout the construction of the bridge the Phœnix wrought-iron columns have been used exclusively for posts and braces.

THE USES OF THE BRIDGE.

When the bridge is pronounced complete in every respect it will have footwalks 4 feet in width on either side, protected by hand railings. There is a single track for railroad travel over the bridge; the distance between the footwalks, 20 ft. 6 in., can be floored over, and used as a carriage or wagon track when not used by trains or railroad purposes.

The superstructure is proportioned for a maximum movable load of 2,240 lbs. per lineal foot, which can only be brought on it by a train of locomotives coupled together. Seven times this maximum load is calculated to be the weight necessary to break it down in all ordinary railroads. The load that it will be called upon to sustain is at most two-thirds of this maximum, so that even more than sevenfold is provided for accidents.

The weight of the iron in the superstructure is immense, and the wrought and cast-iron together will weigh 8,723,000 lbs. There has been 639,000 feet of timber used in the flooring, hand-rails and rail-joists.

WORK ON SUPERSTRUCTURE COMMENCED.

The engineers of the Bridge Company commenced their plans of the superstructure in the fall of 1867, and the contracts for carrying out the same were awarded to the Louisville Bridge and Iron Company, who obligated themselves to furnish the iron-work, ready for erection, from drawings and plans furnished by the

bridge engineers, who superintended its erection.

Great credit is due the Louisville Bridge and Iron Company for the promptness and fidelity with which they have fulfilled this great contract. The most available skill was brought into requisition to make this work unsurpassed in beauty, strength and durability, and their success has been complete, as a thorough examination of the work proves.

The whole of this immense quantity of iron material used, with the exception of the wrought-iron columns, was manufactured in Louisville and New Albany. The Ohio Falls Nail Works of New Albany furnished the wrought-iron proper.

DELIVERY OF THE WORK.

The contractors delivered the canal draw in June, 1868, and on the 3d day of July it was swung in place. As fast as the masonry would permit, the succeeding spans were put in place, and by the close of the season eleven spans on the Kentucky side, and one on the Indiana side, were in position.

The work progressed at each end during the last season simultaneously. On the first day of December the work was so far completed that all the spans were in place except the one between piers 19 and 20, for which the false work was ready, and, but for an unforeseen accident, would have been completed two months earlier.

The disaster, it will be remembered, occurred in the following manner: A steamboat drawing a tow going over the falls in a fog missed the channel, and striking the false work carried it away, taking with it the cribs that supported the trestles, leaving a wide gap at the bottom of which was a large body of water, 16 ft. deep, running at a rapid rate. In the centre of this space was sunk a crib upon which three trestles were erected, the centre one being vertical and those on either side inclining toward piers 19 and 20. Leaning trestles were built from the bottom of these piers, which were connected at the top. On this false work, after a severe trial by freshet, the last span was joined and swung into place February 1st, 1870. Some time was required to change the gauge, but on the evening of the 12th of February, 1870, the first train passed over, consisting of an engine and 24 flat cars.

Since that time trains have been passing at times as required, over the bridge, which has been tested by the severest trials, proving in a most satisfactory manner its entire reliability.

The erection of the superstructure this past summer was a monument in itself of engineering skill and undaunted energy. The span over the Indiana channel was erected over the water, 10 ft. deep, rushing at the rate of 18 miles an hour; some of the pieces weighing five tons, required to be hoisted to their places 160 ft. above the bed of the river. In all cases foundations for the false work were obtained by sinking cribs filled with stone.

To make Screws Hold.—Where screws are driven into soft wood, subjected to considerable strain, they are very likely to work loose; and many times it is very difficult to make them hold. In such cases we have always found the use of glue profitable. Prepare the glue thick; immerse a stick about half the size of the screw, and drive it home as quick as possible. When there is some article of furniture to be repaired, and no glue is to be had handily, insert the stick, then fill the rest of the cavity with pulverized rosin, then heat the screw sufficient to melt the rosin as it is driven in. Chairs, tables, lounges, etc., are continually getting out of order in every house; and the time to repair the break is when first noticed. If neglected, the matter grows still worse, and finally results in the laying by of the article of furniture as worthless. Where screws are driven into wood for temporary purposes, they can be removed much easier by dipping them in oil before inserting. When buying screws, notice what you are getting, for there are poor as well as good kinds. See that the heads are sound and well cut; that there are no flaws in the body or thread part, and that they have good gimlet points. A screw of one make will drive into oak as easy as others into pine, and endure having twice the force brought against it.—*Ohio Farmer.*

Chinese literature has met with a serious loss in the destruction by fire of a wing of the Emperor of China's palace, which contained stores of books and blocks for book printing.

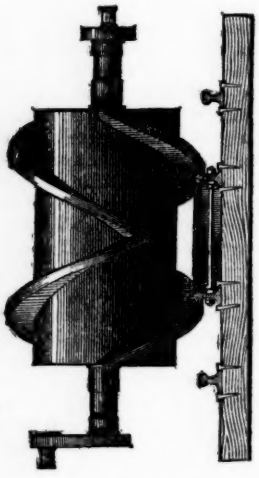
THE WETLI SYSTEM OF LOCOMOTION FOR STEEP INCLINES.

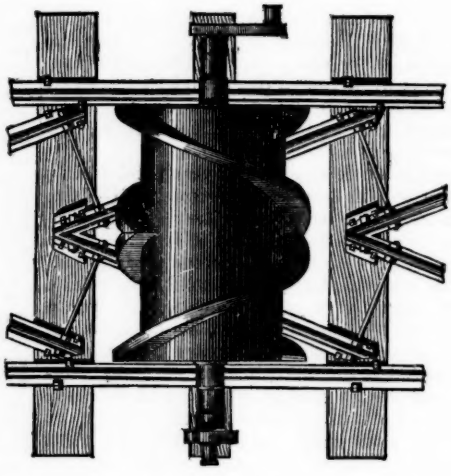
From "The Practical Mechanic's Journal."

The penetration of the great Alpine chains by railways, already, we may say, accomplished over the Brenner and Mont Cenis, and now not far from being commenced over the St. Gothard, and to be followed no doubt, within the next 20 years, by lines over many other great mountain chains in Europe and Asia, has called for several new projects for meeting the difficulties which exist in giving sufficient adhesion with the ordinary locomotion.

Mr. Fell's, originally M. Vignolles's, mid-rail system, as actually at work over Mont Cenis, is one of these ; the highly ingenious Italian wire-rope traction system, as exhibited in the Parc at Paris in 1869, is another. The atmospheric railway system was anterior to all. Mr. Fairlie proposes, on acknowledged principles and without changing anything essential to ordinary locomotive working, to effect this removal of difficulty by merely increasing the number of points of rolling adhesion and diffusing the whole load upon these equally ; and there have been several other schemes which we need not refer to in particular, as being more or less chimerical.

We have now a new proposal, for we





think, whatever else may be said of this system of M. Wetli's, that it is new, in application at least. Our engraved figure will at a glance enable our mechanical readers to comprehend in what mainly it consists. Dr. Hooke's stepped spur-wheels or spiral gear—which is well enough known not to need our referring to it further than to say it consists in engaging wheels whose teeth have faces inclined to the axes of rotation, and may be regarded in fact as portions of the threads of a screw being one wheel, and of an endless nut being the other, and which threads necessarily only touch at one point at any movement, these points of contact passing over the whole length of each tooth successively as one tooth passes after the other ; this system of gear constitutes the basis of the Wetli system. In an ordinary pair of Hooke's spiral spur-wheels the teeth slope only in one direction, *i. e.*, looked at on edge the teeth of either wheel at the axis level slope off lowest at the left-hand or *vice versa*. It results from this that the mutual pressure of the teeth of the two wheels produces a laterally resolved pair of forces tending to cause the wheels to slip asunder sideways or along their axes, were they free to do so, in opposite directions. Were two pairs of such spiral-toothed spur-wheels set side by

side, however, and keyed on their parallel axes with the slopes of the teeth of one pair *reverse* to those of the other, these resolved forces being mutually neutralized, there would be no longer any resultant in the line of the axis of either.

Now, if in place of one of the pairs of such spur-wheels, we substitute a spiral-toothed *rack*, that is to say, a wheel whose radius is infinite, we have complete the elements of the Wetli system. The rack is the railway, between the rails of which are laid two sets of diagonal bars at intervals, pointing towards each other and meeting in the centre of the gauge of way. These are the spiral teeth of the rack. The driving-wheel of the locomotive to be employed consists of a cylindrical drum of the same diameter nearly, and keyed upon the same axis with the main bearing wheels of the locomotive, or upon more than one such axis. Upon the exterior of this drum are fixed projecting spirals which take into or engage with the spiral teeth or diagonal rails of the way, nipping together at two opposite points abreast of each other at the same time, and these bearing points rolling successively from the outer part next the rails to the centre part or middle of the way, and as they roll, dragging on the engine and train as though upon one of the ancient Blenkinsop tooth-and-rack colliery engines and railways of the north of England of pre-Stephensonian days, but always without any rattle or blows or backlash.

Before one double spiral pair of teeth have lost their hold, a second pair as before have got engaged, and so the gear between engine and railway is constant. That locomotion, and very steep locomotion, *can* be thus effected does not admit of doubt; and were it possible to insure such accuracy and exactitude as to gauge of way, position, and firmness of holding down to the sleepers, on the part of the diagonal bars or spirals between the rails, and sufficiently perfect uniformity of level always between the rails and these spirals —in a word, if we could insure such a state of things as we should have were the rails and spirals between them all of cast-steel and in one piece, and bedded and secured down upon solid rock, then we should add that this method had been brought into a practicable state.

Unfortunately, however, such are not the conditions of any railway which are possible, for however short a time; and they are such as the contingencies of traffic, of wear and tear, of weather, and of the accidents of Alpine climates, oblige the widest divergence from, however well a line be designed, or however well its maintenance be attended to. Rails must be secured to sleepers of some sort; these must sit on ballast; more or less elasticity and yield of the way must be provided for. The rails, therefore, constantly alter their level and their position in all three possible directions more or less, and more or less carry with them the sleepers which at once sustain them and hold them to the earth. These spiral bars or diagonal mid-rails must be secured to the sleepers, and so must partake of their mobility. Furthermore, the ballast itself is subject to rain and frost, weather and floods, and often compels movement in the sleepers fixed in it, or goes away altogether, and leaves these partially unsupported.

All these, we fear, inevitable irregularities seem to present difficulties in securing the effective, constant, and certain hold between these spiral teeth in the engine and the rail spirals that appear as yet without a solution.

We do *not* say they are *impossible* to be met, and met within those limits of expense, and of what we may call flexibility in the system of the way, that are indispensable to enable it to be passed round curves, to sustain drought and floods of rain, and so forth, which must be paramount provisions in every permanent-way system.

And we can easily see that some of the doubts and difficulties which first present themselves to the practical consideration, admit of solution. Thus it must occur to anyone that the effect of any slippage upon a steep ramp, between the driving spirals and the fixed rail spirals, must prove disastrous, inasmuch as those spirals which should come into collision again directly after such slippage or loss of bite, would strike each other with the conjoint velocity of the slip backwards of the engine and train, and that of rotation of the driving drum spirals, the engine, too, for the moment, running away nearly as if in free air. But were there two or more driving drums on the Fairlie plan, in some degree under the same or under two closely following

engines, so as to occupy in all several yards in length of the way, such a general slippage would be almost impossible, one or more of the driving drums being always in hold. The *riding* of one spiral upon another by any misfortune would be a more formidable accident, but it is not hard to see that that also may be met.

The inventor of this system, M. Wetli, is an engineer, we believe, engaged in practice in Switzerland; and his system there has seemed sufficiently important and feasible that the High Federal Council (analogous to our Upper House of Parliament) of the Confederation has demanded a report upon it from the Council of the Polytechnic Federal School. That report, signed on behalf of the reporters by M. Charles Pestalozzi, dated at Zurich in August last, was presented to the Swiss Parliament, and has since been published at Berne, along with a very able report by Professor Culmann of Zurich, and a very clear description of the principles engaged has been produced by Professor Gustave Zeuner, whose reputation is well established even in Great Britain, and Professor Georges Veith, also of Zurich.

All these authorities admit the possibility, and are disposed to presume on the feasibility in practical working of the system, the conceivable difficulties and objections presented by which they have very fully discussed.

It is one of those cases, however, to which we may apply the German proverb, "Probiren geht über studiren," or, as they say in the potteries, "Nothing beats a trial." Experiment, and that upon a large and costly scale, and after careful design of the best thought details of plan, can alone really decide whether this would or would not prove a desirable method of railway climbing of Alpine passes.

As regards cost, the official reporters estimate the Wetli way, as designed by the inventor for the double line of St. Gothard, at 767,000 francs per kilometre, or only 15,000 per kilometre greater than that of the same way on the ordinary system of locomotive.

The difference looks small, and the cost may be underrated, but it is to be weighed against that of a tunnel through St. Gothard like that through Mont Cenis, then, as respects first cost, there can be no room for doubt as to which is the cheaper. That, however, is far from being the whole question; maintenance, durability, and cost for traction per ton per mile on the assumed traffic, for a prolonged period, say for twenty years, have to be taken into account if the relative cheapness as methods of transport be really to be compared; and these must present many items in favor of the tunnel, or rather many tunnels, though charged with the interest of a no doubt enormous capital expended in its or their production.

On the other hand, the longest way between two points connected by rail must always be the most costly in outlay and in working, and the moderate gradients *must* always be the longest way.

One form of rack or toothed rail, and different from this of M. Wetli, viz., that of M. Riggenbach, is about forthwith being tried upon a small line of Swiss railway, which, when completed, will probably be one of the most curious, as it undoubtedly will be one of the most interesting, in the world. It has been decided to connect Lucerne with the summit of the Rigi Alp by a line of railway, which, allowing for irregularities in the contour of the ground, is to wind up round the mountain like the fusee of a watch.

The plan of Herr Rach proposed for this does not seem to us nearly as feasible as this of M. Wetli.

Upon the latter plan Signor Agudio, who has given much attention to railway construction of steep ramps, has proposed some modifications, which, however, do not appear to us important as improvements.

In conclusion, this Wetli plan is certainly well worthy of being tried, and there are a good many spots, even in our own country, where the experiment must be made, and, if successful, with permanent advantage to the projectors.

MADRID WATERWORKS.—Although that fine country, Spain, has long been in a state of chronic disorder, and for the last 16 months in the agonies of an interregnum, more than one great work, besides the railways, has been accomplished within the last few years, the principal one being the grand reservoir and aqueduct for the supply of Madrid with good water. The total cost was £2,300,000, including additional work on the principal weir, founded on limestone rock, through which great leakage took place.

ARABIAN DESIGN AND ART.

From "The Builder."

In the course of discussion in a paper by Mr. J. D. Crace, Sir M. D. Wyatt said: I need scarcely remind you that the germs of the Arabian technical and ornamental arts are to be found in those of the Byzantine empire, to which they had for the most part descended from the decaying Roman empire. If there is anything in Mr. Crace's admirable paper to which any one could take exception—a cavilling in which, indeed, it would be almost wrong to indulge—it might possibly be that the speaker's notice of the history of Arabian art scarcely sufficiently carried us back to the stock upon which it was engrafted. The victorious armies of the Prophet and his immediate followers speedily carried Islamism over vast tracts of country, upon many of which technical and decorative arts had long been cultivated with signal success. Hence the peculiar conventional character with which the Arabians so early stamped the eclecticism arising from the junction effected at Byzantium, in Asia Minor, Africa, and Spain, between the Orientalism of Persian and Indian arts (as they existed before the Hegira) and the classical type traditional amongst artists and workmen trained on the system of Imperial Rome. I have myself had occasion to point out in this room the intimate connection which existed between the Persians and Justinian, and its influence on Byzantine art. The peace which was concluded between Justinian and Chosroes Nushirvan was one that was "to last forever," according to the terms of the treaty; and Persian architects were largely employed by Justinian. Thus we see in the details of St. Sophia an evident departure from both the technicalities and the principles which characterized the old Roman works, and a certain marked anticipation of some of those changes of form and predilection for inlay and surface decoration in structure which were afterwards manifested to a great extent in the works of the Arabs. The second aspect under which this subject is interesting to us as practical professional men—students, at least, if not masters, of the handicrafts we control—is the technical basis of this style. This it was which made it vigorous from its earliest date, and has imparted to it the perfection of execution which always characterized it. From first to last it has exhibited the skilful workman compelled to do his best unflinchingly, and obviously to please a master, jealous of good works, who would put up with no half-hearted service. Every artisan, whatever may have been his specialty, engaged on the great works described by Mr. Crace, was a master of his craft, who carried out his work in subservience to the methods and best traditions of his trade, keeping closely to every characteristic of design and workmanship which the materials he used demanded, and which the tools and processes at his command best enabled him to execute. From his intelligence as an operative, his enlightened ideas as a designer, and the perfection which the revival by the Arabian mathematicians speedily effected of the study of geometrical form (which had been carried so far by the ancient Greeks), enabled him to bring to bear upon his special branch of industry, he was speedily in a situation to originate new features in his business, and to make the old ones far more beautiful than they had previously been. Thus in carpentry and joinery, from the very dawn of technical Arabian art, we may observe a clear recognition of the best mode of combining and contrasting, both in form and color, all the various woods which appeared to be at command. Not only was this the case with woods, but we find the same intelligent use with other materials in all the architectural works of the Mohammedans. I differ a little from my friend, Mr. Owen Jones, in what he has remarked with regard to the place and period in which Arabian architecture was most highly perfected. No doubt it is to be recognized in the earlier portions of the Alhambra, as having attained a thoroughly concreted system, in which, as in perfect Grecian architecture, every part had its definite form and dimension allotted to it, without confusion, and with such true and absolutely mathematical design and setting out as to preclude the possibility of

the concurrence of a pattern geometrically inaccurate, or one which does not complete itself in all its parts and repetitions. We find this development of completeness in the Alhambra in its extremest complication, but we find it no less complete, though in a simpler form, in the earlier works at Cairo, such as those of the Mosque Tooloun, and in the Meschita at Cordova. At the same time, we find it associated with better ideas of structure in the technical simplicity of the primitive Arabian system, and in the clear expression of function in every architectural member. Certainly in the Alhambra, with which I am myself better acquainted than with the monuments of the Khalifate, we find the overlaying of the stucco and colored decoration has to a certain extent hidden the structure itself; and beautiful as this overlaying certainly is, and perfectly as it has been made to harmonize with all of structure which is allowed to remain visible, it generally, to my eye at least, obscures too much. In earlier works, both of the Arabs and Moors, a principle of simple masonic construction is always indicated, and the stone is never overlaid by the plaster, nor is the eye misled by the inlays into confusion as to the system of jointing. In thus dwelling upon the beauty of Arabian masonry, I would not be understood for a moment as depreciating the plaster-work (as such) of the whole range of Mohammedan design, from the days of Ebn Tooloun to those of Boabdil el Chico, since during all the many centuries intervening between the reigns of those sovereigns we find, in stucco, admirable hand-worked patterns, executed with a precision and force at least equal to those we meet with in the works of ancient Rome itself. There is one more aspect under which this subject is interesting to us. In the present day there exists on all hands great desire for novelty in the main features of design, as well as in the decoration of buildings. I believe that legitimate novelty in this direction is not to be obtained by a mixing up of styles, or by confusing them together; it is rather to be found in the development in new directions of technical arts, which, if they have not already done so, may in the future be made to minister to the operations of building and decorating. It was by "developing" in this direction that the Arabians found strength, novelty, and completeness of style; and as they did, so may we do. When I look at their tiles, I see one direction at least in which we have been for some time so following on Oriental lead, and I note in them a very legitimate and excellent form of decoration, calculated, I think, to effect a great change in the aspect both of our exterior and interior architecture. I know it has, to some extent, done so already, and I believe it will do so yet more. I see also in this variety of Arabian wood-work, involving an apparently very intricate, though really simple, combination of different patterns, nothing which any skilled workman with the least desire to do what has been so well done, and what seems so thoroughly congenial with a just idea of good joiner's work, would not be able to do perfectly in this country at the present day. When one looks at the rude materials and processes by which elaborate and beautiful works were carried out in almost every technical art by the Arabians, it is difficult to imagine why the same good work should not be designed by us architects, and wrought by our artificers, who should learn to take a pride in their calling, and be honored in proportion to their merit in it, as the Arabian workmen were. All that is wanting is, that the same simple taste, good judgment, and technical energy should be bestowed upon our designs and upon our works. Men are yet to be found in India and Persia, in Cairo, and even in Spain, who, in some degree, retain the theory and practice of the most ancient Arabian tradition. I myself saw in Granada, only a few months ago, a man working with a lathe of the kind described by Mr. Crace; the only difference was, that the lathe I saw consisted of a long iron bar, with "gudgeons" sliding on it, and capable of being fixed by screws at any distance apart. Between these gudgeons a piece of wood was so held as to be capable of gyration, with the least possible amount of friction. The workman sat down with this in front of him, and kept it working with a bow, similar to that constantly used by Indian turners, which twirled the wood round rapidly on the iron gudgeons. This he did with his left hand, while with the right hand he steadied himself, changed his cutting tools, and measured from

time to time the gauge of the work he was doing. For what right hands usually do with ordinary lathes, he substituted his right foot, which exhibited an elongated great toe just like a thumb, and a metatarsal development such as I never saw before. He held the chisel tightly between the great and second toe, and seemed to use his foot just as easily as we ordinarily use our hands. It was curious to find at Granada such a retention of the simple machinery and method by which it is probable that the Moors executed the bulk of their larger ornamentations in wood, dependent upon the lathe for the fashioning of their leading forms. I trust I may be permitted to allude to one more point before I sit down; and that is, the opportunity for surface decoration which was afforded by the large wall surfaces in which the Orientals have always delighted, and by their simple arch soffits and vaults, rarely cut up by moulded work or chamferings. I cannot help thinking that these remarkable "reversible" patterns which we see here, and the effect of which is invariably excellent, were probably originally due to the desire to economize labor and cost by making one piece of material serve, by counterchanging and interchanging the parts into which it was cut, to produce patterns in different colored materials without the waste of any portion of material. At the same time I cannot but consider that, speaking theoretically, patterns so formed appear to be in strict compliance with that which was, and should be always felt to be, a bounden duty to carry out in colored decoration, viz., equalization of superficial areas of contrasting colors in the design of patterns intended to convey a sense of tranquil beauty. The principle was no less important when the contrast was intended to be effected by *chiaroscuro* only or by variety of materials, than it was when the effect was intended to be produced by contrasting colors. Equalization was demanded of the light and dark shades. It is such regular balance which keeps ornamentation quiet, and which gives to it its dominant aspect of repose. Balance, it should always be remembered, is just as essential to repose in decoration, as equilibrum is to security, and its appearance to a sense of security, in structure.

A NEW GUNPOWDER.

From "The Scientific Journal."

Among the many practical applications of phenic or carbolic acid, not the least important is its use in the preparation of picric acid, a substance which, in combination with potash and other bases, promises to be of great value to the arts. Although readily produced from other substances, carbonic acid appears to be the most desirable source of supply, and only requires to be treated with concentrated nitric acid. A combination takes place with a hissing noise, and results in the formation of picric acid, in long lamellar crystals of a beautiful lustrous yellow color, and of an intensely bitter taste. Already used extensively in the preparation of dyes, it is, as an explosive, of peculiarly valuable properties, that we now call the attention of our readers to it, as when heated suddenly to the proper degree, it decomposes with explosion, and this peculiarity is increased when combined with an alkaline base. The picrate of potash is the most important in this respect, and has lately been the subject of extended experiment on the part of an eminent French chemist. This is a salt of a beautiful golden yellow color, crystallizing in prismatic needles, and while insoluble in alcohol and nearly so in cold water, dissolves readily in fourteen parts of boiling water. Heated carefully, it acquires an orange red color at 572 deg. Fahr., which it loses on cooling; heated rapidly to 620 deg. Fahr., or brought in contact with red hot bodies, it explodes violently. It is most readily prepared by the double decomposition of a soluble picrate of soda, magnesia or lime, and a salt of potash, or by the direct action of picric acid upon the carbonate of potassa. The explosion of the picrate gives rise to an immense volume of gaseous matter, as nitrogen, carbonic, and hydrogen and oxygen, and the only solid residuum is a little carbon and carbonate of potassa.

The smoke produced is very light and easily dissipated, and the gaseous products are totally destitute of the corrosive and poisonous action of those of gunpowder, with their thick, heavy, stifling smoke. Nearly insoluble in cold water, there is no absorption of moisture from the atmosphere to deteriorate its quality or destroy its utility, as with gunpowder, so that it may be used in the dampest mines, where also the almost total absence of smoke and of noxious products after explosion, is a great recommendation.

Two varieties of the picrate powder are now manufactured, one for blasting, the other for fire arms; each made of various grades of strength and adapted for special applications. For the first purpose, nitrate of potash is used with the picrate; for the second, an additional ingredient, charcoal, is employed, the latter being added to diminish the rapidity of the combustion and increase the projectile force. This can be regulated so as to be greater or less than that of gunpowder, while the blasting power is much greater than that of the latter substance.

Our space will not permit us to go into mere detail respecting this new powder, which is so easily made and kept unchanged, and can be made of any desired degree of strength, and in its explosion yields no deleterious or corrosive gases, blinding smoke, or acrid and troublesome residuum. It is nearly as cheap, and less easily ignited by carelessness or accident, than gunpowder. Of much greater blasting power, and quite equal to nitroglycerine in this respect, it seems destined to play a very important part in mining operations, while the comparative absence of solid deposit renders its use in gunnery highly advantageous. The color is a brilliant yellow, and thus it is easily distinguished among other substances. It is also of varied application in pyrotechnics.

In conclusion, we may state that the picrate powder is the subject of extensive and secret experiment with the French Government, which will probably use it before long as a substitute for the old-fashioned black gunpowder, in its military and naval service.

THE BOUTET BRIDGE.

From "Engineering."

From the first effort of M. Charles Boutet to make English converts to his proposed system (?) of building bridges in impossible spans, we have not hesitated to say in plain words what we thought of the invention, and we have from time to time given out our opinion with so much of force that we believe we have effectually counteracted all the endeavors of the projectors of the so-called Channel Bridge Scheme to gain shareholders in this country. Whether this wonderful association still exists here, we know not; but this is certain, that M. Boutet cannot with any chance of success bring his plans again before the public, although very possibly the favorable notice his scheme received lately at the Society of Engineers may gladden him with delusive hopes.

So far, so good; we may consider ourselves done with Boutet, but, as our readers know, from time to time the French papers have been not unfrequently conspicuous for flourishing descriptions of Boutet and his bridge. Now, it was a picture of the Emperor inspecting the models at the Depot des Marbres, now an announcement of the construction of a Boutet bridge at St. Malo, now a promise of the almost immediate commencement of the great Channel bridge itself. Some of these paragraphs translated may have been seen from time to time in English papers, but beyond this we know nothing, for the narrow strip of troubled water which isolates us from the Continent serves also as a great non-conductor of intelligence, and cuts us off from many details of information, which the mere distance does not account for.

A minute report, however, of the progress of the great international bridge scheme lies before us, the joint production of MM. Hauvel and Lockert, two engineers of the Ponts et Chaussées. We believe that this report will shortly be published in the French scientific press, and it will doubtless be received with much favor. "You ask," say MM. Hauvel and Lockert, "intelligence of M. Ch. Boutet,

engineer: he is always in Paris, always devoted to his vast project of the Channel bridge, always to be found at the Depot des Marbres. What do people think of him? Truly, those who can think, don't think of him at all. But he works hard. Each day he explains with affability to every visitor, possibly a future shareholder, those principles, not less simple than ingenious, upon which the bridge is constructed; he produces immense plans, medium-sized plans, little plans; he handles lengths of wire cables of all dimensions, he expatiates on the weight of the structure, its cost, its future prospects; and, inspired by the proximity of an Imperial bust, which imparts an august influence to his bureau, M. Boutet inscribes another convert's name in the subscription book; the day's work is done, and the great scheme is furthered by so much. What scheme? The Channel Bridge, doubtless, with its span of 1,000 metres. It was Marshal Vaillant, who, taking an early interest in this project, accorded to the inventor a place on the ground of the Gardes Meubles, at the Depot des Marbres. So one great difficulty was removed, and the affair became sheltered as it were under the shadow of Government. Then the needful funds obtained, an engineer (!) and staff of draughtsmen commenced their labors, the latter operating on the largest sheets of paper procurable, the former working out a mathematical theory to correspond." This theory, the only so-called scientific production in connection with the affair, was published in the "Annales du Génie Industriel" of Feb., 1869. A wonderful ignorance characterizes this work. The question is thus stated to prove that a span of the Boutet bridge can be constructed with an opening of 1,000 metres, of the form and dimensions figured in the drawings: "The span has the form of an arch; the strongest section is required at the abutment; the springing is therefore the only part of the structure we need investigate, and prove correct, for the rest of the span will always come right, provided we give the arch a parabolic form." This is still better: "Let us seek, now, the section at the springing; nothing is more simple; apply the formula." Fortunate formula, to be so accommodating. But in the place of applying a formula relating to an arch, one is used which is applicable only to straight girders. Add to this that the weight of the structure is thrown out of the calculation, and an unique result is obtained, which bears out the assertion of M. Boutet: "We are thirty-six times stronger than we need be." But despite all these egregious blunders, there is little to be wondered at that not a few speculators of hazy notions have ventured more or less in this wonderful bridge scheme. But so much of popularity as M. Boutet has obtained in Paris is due principally to the indifference of French engineers, who deem the whole business too unworthy of their notice. Not that the inventor would be daunted by criticism, but silence is construed into an acknowledgment of merit. On one occasion, indeed, it is said that four young engineers of the Ponts et Chaussées had the audacity to laugh outright in the presence of the presiding genius, saying: "If you will undertake to build a bridge upon this remarkable and unique system 100 metres in length, and which will bear its own weight, we will pay for it." Whereupon M. Boutet goes forth straightway, grave, and full of serious purpose, saying to all around, "Messieurs, the engineers of the Government have instructed me to build forthwith a bridge upon my system 100 metres long."

On the 8th of June last, Fortune visited M. Boutet, embodied in the Emperor, accompanied by General Fané, Marshal Vaillant, and several members of the Academy. But this was hardly, perhaps, the crowning glory, though, possibly, its results were highly gratifying. It was at Vervius and St. Malo that this truly remarkable man reached the climax of his greatness. Deponent saith not how or why he became fêted and a hero; nor whether the musicians, firemen, and other elements of a provincial demonstration, celebrated him on similar terms to those of the serenaders of Artemus Ward. Nor is it clear how it came to pass that a Prince of the Blood, a Grandee of Spain, in short, the Duke of Saldana, met him, embraced him, and said of him, "Behold one of the greatest men of the century!" But these things happened, and we give M. Boutet his due. And, after all, M. Boutet is a remarkable man. We have ere this glanced at his antecedents, let us now record one of his previous works. On

the 6th of July, 1858, he obtained a patent entitled, "Hydraulic Motors, applicable to all cases in which power is required." This contrivance is, in fact, a perpetual motion, nothing less. That is something, but not enough for M. Ch. Boutet, as he states in his specification: "This last system (he patents three) is superior to the two first, because it is evidently more simple, and gives, with equal means, double the power." So that this ingenious creature has positively devised three systems of perpetual motion, the last of which is twice as perpetual as the two first.

After this, we need be surprised at nothing that M. Boutet can do; 1,000 metres bridge spans are a mere trifle; and equally it is little to be wondered at that the subscriptions for the scheme amount, it is said, to some 200,000 francs. All we can say is, that we have reason to be glad that the sum has been paid in francs, and not in pounds sterling; that it has come from French purses, and not out of English pockets.

HOISTING STONE IN QUARRIES.

From "The Mechanics' Magazine."

The dangers that attend the men who go down to the sea in ships and transact their business in great waters are scarcely greater than those which await the toilers who descend into the bosom of the earth to win the mineral treasures to which this country in particular owes so much of her greatness. Whether it be in the mine or in the quarry, death or disablement are there awaiting the unfortunates who may happen to fall a prey to them. In the case of mines, we hear too frequently of fatal catastrophes, but, strangely enough, the disasters which occur in quarries rarely find their way into the columns of the press, perhaps because each disaster is, in itself, too insignificant as compared with the wholesale slaughter of a colliery explosion. We have good reason, however, to know that the annual loss of life and limb in quarrying operations is by no means trivial; unfortunately, too, a large proportion of these quarry accidents are more or less preventable by improvements in the hoisting machinery and appliances used to raise the stone when hewn, to the surface of the ground. The present arrangements for lifting may not be familiar to some of our readers, so we will briefly describe them.

A large quarry in full work presents a considerable area of operations, and, as a rule, there is but one engine to hoist the material; this is usually placed on the edge of the quarry at the end of the tramway along which the stone is taken when raised. The engine is generally on the surface ground, but a sort of step or recess is cut close alongside it, and whose level is about ten feet lower; the tramway is brought to the edge of the quarry along this step so that the lorries for the stone are beneath the engine level. In a large and deep quarry it is evident that nothing in the way of a jib crane can be made available, and a gantry and traveller would be too expensive even did such an apparatus give sufficient scope to reach all the area in work. Instead, therefore, of either, the following plan is adopted. A large chain is stretched from the engine-house across quite to the other end of the quarry and there secured, but not permanently so, this end being shifted from time to time as the position of the stone being hewn requires. On this chain a sort of carriage runs; it is something like an iron block, with two sheaves set side by side in the direction of their diameters, not of their axis. They are wide and deep enough in the grooves of their edges to run on the chain as on a rail. This block carries a real block, or what answers to one, suspended under but close to the chain; through this the rope or chain for lifting is passed.

It will be evident that the hoisting rope has a merely vertical action, but the block, or "horse" as it is technically called, gives both a vertical and horizontal motion, as the chain is most generally on a considerable inclination.

The *modus operandi* is as follows: When a certain stone is to be raised the chain is moved over it and the quarry end made fast. The "horse" is run along the chain till "plumb" over the stone. A "toggle" or pin is secured in a link be-

hind it to prevent it moving down the slope of the chain and the hoisting rope is paid out and the stone hooked on, which is raised till the lifting hook reaches the "horse," when it is secured to it. The engine then draws the "horse" along the chain till the stone is fairly brought out of the quarry, and over the step already described, as well as over a lorry placed there in readiness. A "toggle" is put into a link of the chain to prevent the "horse" going back, the stone is lowered into the lorry, and the operation is complete.

Any person with the most moderate knowledge of engineering must perceive that, however cheap and convenient this arrangement may be, it is fraught with danger to those working or passing beneath the chain; the very best chains carefully tested are uncertain affairs even when subjected to a simple statical strain, and the strain of the main, or, as we may term it, "gantry" chain in a quarry is not a purely statical one by any means, as the "horse" when it begins to move "jumps" over the links sufficiently to cause a considerable "jar," which, as a matter of course, is constantly breaking the chain, or if the hauling chain or rope from the engine happen to break, the "horse" runs violently down the incline of the chain and the latter, already perhaps loaded nearly to its limit of strength, succumbs to the vibration, and the stone and ends of the fractured chain in all probability fall on some luckless workman beneath.

We have good reason to know that appalling accidents from this cause are common, a fact scarcely to be wondered at seeing that there is no adequate inspection of the arrangements of quarries, and the chains and whole apparatus are of inferior quality in too many instances.

We will proceed to sketch the outlines of an arrangement which we consider to present some advantages over that already described. The chain should be abolished altogether, and either a steel wire rope or a rail substituted. The rope would be little, if at all, more expensive than a chain, while it would be infinitely more trustworthy; less power, too, would suffice to raise the loads, as the wheels of the "horse" would have a comparatively smooth and uniform surface over which to travel. We believe a rail might be arranged made of round iron jointed much as a gas pipe is, the ends of the joint sockets being rounded on their outer edges to give freer passage to the wheels of the "horse." Instead of the "toggle" used with the chain to prevent retrograde motion, a "clip" should be put on the rail (or rope) made of two pieces of iron hinged at one end and with a coach screw at the other, each half being nearly semicircular in the centre; this part would embrace the rail, and if screwed up tightly would prevent backward motion, or at the worst would act as a brake if the strain were too much for it. As to the catenary formed by a chain or rope the rail would equally well assume that curve, as if of good iron its diameter need not exceed by more than one-half that of the round iron in the chain links, and being without a weld would be reliable to an extent such as the very best chain can never equal. This round iron rail arrangement would be far cheaper, too, than the chain.

It is a discredit to us as a nation at the head of civilization and engineering science that such rude appliances as that described in the beginning of this article should be retained to the exclusion of better ones.

As projects of importance in Northern Germany may be mentioned: 1. The Great Canal from the North Sea, near the mouth of the Elbe, to the port of Kiel, on the Baltic. The plans are fully prepared, and the works estimated at about five millions of pounds sterling. 2. A new Port of Commerce and Refuge on the Western Coast of Sleswig, where the island of Rom is to be connected by an embankment of about 3 miles long, with the coast, the port on the island being thus brought into communication with the continental railway system. This harbor is expected to be the most accessible port on the German coast under all circumstances of wind and weather. The works are estimated at about £750,000 sterling.

A Trinity steamer has taken out men and stores from Penzance for the building of a new light-house near Ceylon, under the superintendence of Mr. Douglas, who has lately completed the Wolf Rock Lighthouse.

EFFECT OF SUDDEN LOADS ON CAST-IRON.

From the "Building News."

Brittle substances are usually defined by physicists as those in which the force of cohesion is comparatively weak. Their particles, or component atoms, are therefore held somewhat loosely together, and when exposed to strains of certain descriptions, possess little or no resistance. It will probably here be observed that many brittle substances are endowed with very considerable powers of resistance to a crushing force, although they display but very feeble tensile strength. This is no doubt true. Cast-iron, for instance, will stand a direct crushing force of 50 tons to the square inch, while its tensile strength is only 8 tons to the square inch. But the real strength of the material is only to be depended upon when the crushing force is applied in a particular manner. It is not so much a question of the amount of the force, as of the manner in which its action is exerted. When it is stated that cast-iron will bear a crushing or compressive strain of 50 tons per square inch, it is always presumed that the strain is applied to the material in a similar mode to that which prevailed at the experiments which fixed that constant. Whenever the weight of 50 tons, or other crushing weight, is imposed upon a square inch of cast-iron, it is supposed to be by gradual and almost imperceptible increments, commencing with a very small weight, and terminating with that which ultimately determines the fracture of the specimen under experiment. If, on the contrary, the weight be applied suddenly and violently, the material will yield to one very much less in amount. It is this liability to give way under a sudden strain that has rendered engineers so very cautious in employing the material in any situation where it might, perhaps, inadvertently be exposed to its influence. By an excess of caution, cast-iron is frequently, from the same cause, debarred from being applied to numerous useful purposes to which it is perfectly well suited, and in which it might be adopted without the slightest fear of disastrous or unforeseen consequences. It is, no doubt, advisable, especially for young members of the profession, to be "on the safe side," as it is termed; but nevertheless, while adhering to the example of precedence, and the result of experience, one must not be afraid to employ a constructive material simply because its employment has been in some instances attended by failure; however, it should not be forgotten that the majority of these failures occurred in the early days of railways, and were due more to the incompetency and rash judgment of the designers of the structures than to any real defect in the material.

At present it may be safely presumed that our knowledge of the nature, properties, and capabilities of cast-iron under strain, is more complete than it previously was, and it might therefore be concluded that bridges and other structures of that material were not likely in future to be subject to such contingencies. No doubt such accidents are rare, but that they still happen is demonstrated most absolutely by the occurrence that took place recently at the bridge of Elkantara, in Algeria. A description of this bridge will be *apropos* to our present article, and very instructive to those who may have the designing of works of the same or similar character. In the first place, let us briefly relate the accident. A roller of 5 tons in weight was traversing the bridge backwards and forwards for the purpose of crushing the metalling and bringing it to a smooth surface. On a sudden the roadway gave way. The horses attached to the roller were able to maintain it for a few minutes in a suspended condition, while the driver cut the traces, when it disappeared into the gulf beneath with equal noise and rapidity. The ravine across which the bridge of Elkantara is thrown is nearly 400 ft. in depth, so that both driver and horses had a very narrow escape from being dashed to pieces. The span of the bridge, which is wholly of cast-iron, is 184 ft., and the clear width between parapets, 33 ft. There is not the slightest difficulty, in the present instance, in arriving at the cause of the accident. It was the breaking of one of the cast-iron plates constituting the roadway, under the heavy rolling load brought upon it. There are altogether five arched ribs composing the framework or main girders of the bridge, two of which are the face or outside ribs, and the oth-

ers the interior or intermediate ones. These latter are spaced about 9 ft. 9 in. apart, and the whole are braced together by cross girders and trussing, also of cast-iron. The transverse girders are of a plain T section. Upon the intermediate arched ribs are placed the cast-iron road plates, their span being nearly equal to the distance between the centres of those ribs, which is evidently a long span for cast-iron plates in the situation under description. The plates are slightly cambered, and their average thickness is 0.8 in. That of the metalling is about 10½ in. The framework of the structure was not in any degree affected by the accident.

A glance at the construction of the bridge at once points out that the contingency was, in the main, due to an attempt at false economy. The design clearly was to dispense with the usual transverse road beams, and make the cast-iron plates do the double duty of acting as road plates and girders at one and the same time. The shape and section of material that will answer perfectly for a road plate pure and simple, where the span does not exceed 3 ft. or 4 ft., is not by any means adapted to situations where the span becomes nearly 10 ft. It is somewhat extraordinary that the French engineers, who, as a rule, calculate the action and effects of strains upon bridges a great deal more precisely than we do, should not have appreciated the exact nature of the case. At the very first sight, a road plate of cast-iron nearly 10 ft. in span is a very unusual piece of construction, and it could not fail to strike one that in that position it would be acted upon by other strains than that of compression. Cast-iron in the shape of a road plate is not adapted to undergo tensile or transverse strain, and even in the best form, namely, that of Mr. Hodgkinson's girder, it is not altogether reliable under a heavy impactive or concussive load. In addition to these theoretical objections, there are also others of a practical nature. When the ratio of the thickness of the plates to their superficial dimensions is considered, it is not an easy task to insure that the casting should be thoroughly, uniformly, and homogeneously manufactured. Any flaw in it, which might, under less trying circumstances, be of no importance, would be fatal to a plate in the situation it was placed in at the bridge of Elkantara. On the score of weight, both cast-iron plates, and the still older practice of using brick arches, to carry the roadway, are objectionable. They are now nearly obsolete with us. Wrought-iron corrugated or buckled plates are the means usually employed by English engineers for supporting the roadway of public bridges, but even in that case their span does not attain to the dimensions of the cast-iron plates which have been just described. The cross girders of a bridge require depth, the road plates, superficies, and it is impossible to combine the two in one without the chance of danger, or incurring an unwarrantable expense.

NARROW GAUGE BRANCH RAILWAYS IN SWEDEN.

From "The American Railway Times."

Since the adoption of the 4 ft. 8½ in. gauge in 1854, as the standard for all main lines, about 400 miles of narrow gauge have been built, both by the State to aid their trunk lines, and by private corporations, and have been operated with very satisfactory results. The 4 ft. 8½ in. gauge has been built at an average cost of $3,250, gold, per mile, and brances of the same gauge, but lighter rails, superstructure and equipment, at an average of $2,300, gold, per mile. The following is a partial abstract from the report of the State Engineer, Major Adelskold, of a narrow gauge road lately built by him, and of others previously built and operated under his charge. He says:—"This short 23 miles length road, between the iron works at Ullinbord and the Maelar seaport, runs through a district in which several large iron-works and saw-mills are situated, and connects that district with the small town of Koping on the Maelar Sea, and the Royal Swedish Main Line. The gauge is 3 ft. 7 in., embankments 13 ft. wide; rails 37 lbs. per yard, secured by splices fastened with four bolts; ties 6½ ft. long, 5 in. thick and 8 in. wide. Grades arranged as follows: from the interior to the sea-

port, in which direction the heaviest traffic is carried, the heaviest grade is 1 in 200, and in the opposite direction 1 in 100; shortest curve 1,000 ft. radius. There are six stations on the line, including the terminal with all the necessary buildings, sidings, turn-tables, switches, etc. The rolling stock was built in Sweden, and consists of 3 locomotives of about 13 tons weight, 9 in. cylinder, 4 wheels coupled, 3 ft. 6 in. diameter; 50 cars for freight, and 6 for passengers. The locomotives have cost about $7,000 in gold. The freight cars are of 6 tons capacity, 16 ft. long, 6½ ft. wide, and have cost $225 each. The passenger cars are arranged for first and second class passengers. The average speed is 16 miles per hour, and 35 miles have been run on several occasions, causing but very slight oscillation of the cars. The cost of this road has been—complete in every regard, including telegraph—$9,700 per mile; and the cost of operating the same for the first year an average of $650 in gold per mile per year. The travel is as yet not fully developed, and by doubling the number of cars, 100,000 passengers and 150,000 tons of freight could be carried without difficulty.

"There are a number of other narrow gauge roads that have met all the requirements made of them, and realized the expectations of their owners in every respect. Two of these are 4 ft. gauge, one 26 and the other 56 miles in length, and are branches of the Swedish main line. Prior to the completion of the first, it was generally believed that the transfer of freight from the branch of the main line would involve considerable outlay and serious loss of time. This objection has, however, proved to be very trifling, as the cost of transferring, when cars are placed beside each other and with suitable arrangements, will not exceed two cents per ton.

"One of my principal doubts was the ability of these light and small engines to keep the road open during winter. The experience of several severe winters, however, has shown that no such fears need be entertained."

He closes as follows:—"In every case where the narrow gauge roads have been built, they have realized every expectation, and I deem it a waste of capital to build broader gauges when a narrower and cheaper will meet all requirements, For as thinly-settled country as this, where the available capital will barely meet the wants of the rapid industrial and agricultural developments, and where cheapness of transportation is of so great importance, the narrower gauge may in many localities be well adapted, if not positively necessary, as they can be easily built and at such cost, that with but a small traffic, they are able, not only to cover the cost of operating them, but pay a good interest on the capital invested."

Wire Rope.—Wire rope, wire cord, and wire clothes lines have been brought into such general use, that articles of this character are no longer a curiosity. One of our exchanges thinks that wire rope and wire cord constitute one of the most decided improvements on the ideas of our grandfathers that are entitled to attention in our enlightened age. The snapping of a sash cord, which leaves a window a heavy burden on all connected with it, has ever been the dread of housekeepers. But the *wire sash cord* at once insures the most nervous against such accidents. For clothes lines, the wire rope must supersede the old hempen arrangement, as it is not only strong but durable. Dumb waiters find in it a reliable way of elevating themselves without fear of disconnection. Pictures in costliest frames may hang most favorably from *silvered* cords that look like shining thread of lightest gossamer. And speaking of gossamer reminds us that wire cloth is manufactured by the same company that make the iron, copper, and silvered sash cord. Even lightning rods are formed of copper wire, so plaited as to be continuous, and therefore not too apt to puzzle the electric fluid with a single joint in its free and easy passage to the earth. The cars of the elevated railway, on Greenwich street, are to be propelled by wire rope belts, a mile in length, extending from the driving wheel of one engine to the large pulley-wheel, half a mile distant, and back to the engine.

A new bridge is to be built at Maldon, Essex, in lieu of one which is 600 years old. Mr. J. S. Cooke, of London, is the architect.

PERFORMANCES OF ENGINES.

By W. H. G. WEST, Engineer, U. S. N.

From the "Journal of the Franklin Institute."

The following is a statement of the performances of a number of engines, collected from different quarters, by engineers of undoubted knowledge and integrity.

Condensing cotton mill and engine at Chester, Pa. Diameter of cylinder 20 in. Stroke 4 ft. Steam cut off about 1 ft. from commencement of stroke. Steam pressure 61 lbs. above atmospheric. Boiler, tubular; locomotive pattern. Coal consumed per horse-power per hour, 2.35 lbs. Duration of trial 60 hours. For one day of the trial the consumption was only 2.057 lbs. per hour, for each horse-power. Chestnut coal gave the best result; and if used during the whole trial, would probably have brought the consumption below 2 lbs.

Non-condensing cotton mill engine. Diameter of cylinder 14 in. Stroke 3 ft. Cut off at about ¼ of stroke from commencement. Cylinder boilers. Steam 80 lbs. above atmospheric. Consumption of coal 3 lbs. per horse-power per hour.

Condensing cotton mill engine. Diameter of cylinder 28 in. Stroke 5 ft. Steam pressure 110 lbs. above atmospheric. Cut off varied by regulator. Jacketed cylinder. Tubular boilers. Consumption of coal per horse-power per hour, 1.9 lbs.

Brooklyn Water Works Engine.—Diameter of cylinder, 90 in. Stroke 10 ft. Flue boilers. Consumption of coal per horse-power per hour 3 lbs.

Average performance of a number of stationary engines of and about 20 in. diameter of cylinder, 4½ lbs. of coal per horse-power per hour.

Babcock and Wilcox engine, jacketed, 3½ lbs.

Greene's engine, 3¾ lbs.

Corliss engine, non-condensing, 3½ lbs.

Average performance of a number of Cornish engines. Diameter of cylinders 50 in. and upwards; about 3¾ lbs. per horse-power per hour.

U. S. S. "Wampanoag," running 18 to 20½ statute miles per hour, after making all allowances for friction of load, etc., and so bringing it to the same condition, in regard to duty, as the Cornish engine, 3.129 lbs. per horse-power per hour.

U. S. S. "Ammonoosuc," running 18 to 20 statute miles per hour, 2.65 lbs. per horse-power per hour.

H. B. M. ship "Constance," *Woolfe* engines, with jacketed cylinders. Steam expanded from 8 to 10 times. Surface condenser. Consumption of coal per horse-power per hour, 2 lbs.

In presenting these proofs of the correctness of a former assertion that many American, and other rotative engines, will compare favorably with the majority of Cornish engines, I do not wish to imply that the above performances are the best obtained from the engines named, but that they are sufficient to prove more than equality. In collecting them, I have been forced to the conclusion, that either the construction of the Cornish engine is not particularly well understood, by the present manufacturers of that interesting machine, or that the old plan of guessing at coal, by the barrow load, led the experimenters of that time astray.

More than 20 years ago the duty was said to have come up to 130,000,000 lbs., lifted one foot high, by the consumption of 112 lbs. of coal; but for May, of this year, the average for eighteen of them was only 50,100,000, and it will be found that this is the general average.

Several writers have distinctly stated, in the "Journal," that the weight of the moving parts is the principal cause of the superiority of this engine, and much importance is attached to the fact of its having a beam; but we know very well that the weights are nearly the same as in old times, and that the weight of the engine beam is exceedingly small, when compared with the weights of rods, balance-beams, etc., which belong to the pumping apparatus, and which must be used with any kind of engine that may be employed. Can prejudice possibly be so strong as to compel any one, even to insinuate, that a slight variation in the strength of parts will make a difference of 80,000,000 lbs. in the duty?

In accepting, as sound, the arguments of the gentlemen who have recently written so warmly and forcibly in favor of these engines, there is nothing left but

to believe that those built in late years are very badly designed. Mr. William West, the designer of the 80 in. at Fowey Consols, would not feel complimented, were he to hear that the success which he sought to achieve by improvement in every detail, was due to clumsy bulkiness.

It is stated in a paper upon steam jacketing that, *practically*, the expansion of metal is nothing, in the Cornish engine cylinder. This is repeating the old story, that theory does not agree with practice, and is an expressed doubt of the ability of such men as Joule, Faraday, Tyndall, Regnault, and others of equally high reputation, to make practical experiments. A beautiful set of experiments is recorded in the November number for 1869, showing the number of vibrations of piano strings in making the different notes; but *practically*, we have every reason to doubt the truth of the statement, because we do not see the strings flap about, like the sails of a ship taking in a gale of wind.

At one end of the Cornish cylinder we have a high pressure, say 60 lbs., the temperature of which is 292.6 deg. Fahr., and at the other end 90 deg.—condenser temperature. Cast-iron expands lineally .0000618 per unit, for each degree of heat added above these temperatures. An 80 in. cylinder will therefore increase its diameter full 0.1 in. The temperature of the piston will be a mean between the other two, and the thickness of the piston being about ten times greater than that of the cylinder, its temperature will not change as rapidly; indeed its diameter will be nearly constant. If it fits well at one end, it must therefore jam, or leak steam at the other. *Practically*, my attention was first drawn to it by one who had observed it in the Fowey Consols 80 in. when an attempt was made to move her, before the steam, passing from the boiler to the jacket, had heated the cylinder all through. After steam had been admitted to the lower end, the engine worked as usual. The difference of temperatures, in that case, was probably 250 deg.; and the difference of diameters almost exactly $\frac{1}{4}$ in. In the same circumstances, the 110 in. cylinder, now being made for the Bethlehem Zinc Mine, Pa., would have a difference of diameter of over $\frac{1}{4}$ in.; and the 144 in. built by Harvey & West, of Hayle Foundry, Cornwall, England, for Holland, would have a difference of diameters of 0.22 in. (nearly $\frac{1}{4}$ in.). Would that be a *practical* leak? The very high steam that some people say is used in Cornish engines, would make the leak greater.

Rankine, in his "Prime Movers," page 568, compares the effects produced with, and without, the steam jacket. The ratio of whole gross work of steam to gross work during admission, will show which does the most work during expansion and will be

$$\frac{\text{mean pressure} \times \text{ratio of expansion}}{\text{initial pressure}} = 3.55$$

for the unjacketed cylinder, and 3.73 for the jacketed cylinder; showing decidedly in favor of the jacket. Condensation in the cylinder, is shown by the ratio

$$\frac{\text{initial pressure}}{\text{mean pressure}} = 5.64$$

for unjacketed cylinder, and 5.36 for jacketed cylinder; giving a much greater condensation in the unjacketed cylinder.

The same writer for the "Journal," says, that "there is no doubt that a higher degree of expansion is possible with a steam-jacketed cylinder." There lies economy.

I cannot see how admitting more steam, already on the point of condensation, can prevent other steam, with which it is brought into contact, from condensing, as all must expand together.

Steam, in the steam jacket, superheats the expanding steam in the cylinder, by the loss of its own heat, and thereby prevents condensation in the cylinder, to a great extent. It is not supposed to vaporize any that may lie upon the piston, except through the superheated steam in the cylinder.

Two questions arise in regard to steam jacketing: 1st.—Whether it is better to condense steam in the cylinder, thus assisting the condensation by expansion, and to expand the remaining low steam, or to condense steam in the jacket, and get the benefit arising from the use of high steam, together with the increased economy of a high grade of expansion. 2nd.—Whether the heat remaining in the water, into which the steam is converted, should go to the condenser to destroy the vacuum, and the water itself to load the pumps or go back to the boiler, for further use. I should say the latter, in each case. Although it is very right, and proper, for each one to judge for himself, some little

weight should be given to the experience of Watt and other prominent men who have pronounced in favor of the steam jacket.

In the August number of 1869, page 11, we find the following: "A Cornish engine is now running which produces a lower duty than a double acting high pressure fly-wheel engine, used in the same works illustrating *defects in construction*." This assertion is, without doubt, true, and the writer probably refers to the wonderful thing recently built for Spring Garden or some other Philadelphia Water Works, but which is really not a Cornish engine; or to that singular pair of twins in the West Philadelphia Water Works, that were designed to be Cornish engines, but are not, and which obstinately persisted, for a long time, in pumping water during the latter part of the stroke, only. I am glad to see that some one has the courage to compare them (unfavorably too) with the least economical type of rotative engine.

In the editorial note, September number, 1869, page 159, we find it is stated that 18 Cornish engines averaged a duty of only 50,100,000 lbs., lifted one foot high, by consumption of 112 lbs. of coal, or 447,321 foot lbs. for 1 lb. of coal. A horse-power means 33,000 lbs. lifted one foot high, in a minute, or 1,980,000 lbs., lifted one foot high, in an hour. Dividing this by the number of lbs. of coal consumed per horse-power per hour, we have the number of lbs., lifted 1 foot high, by the consumption of 1 lb. of coal, and proceeding thus with the statistics already given, we have the following results, showing the comparative economy of the different engines:

At 1.9	lbs. per horse power,			1,042,105 ft. lbs.	for	1 lb.	of coal.
" 2.	"	"	"	990,000	"	"	"
" 2.65	"	"	"	747,169	"	"	"
" 3.	"	"	"	660,000	"	"	"
" 3.125	"	"	"	632,790	"	"	"
" 4.5	"	"	"	440,000	"	"	"
" 3.75	"	"	"	528,000	"	"	"
" 4.42	"	"	"	447,321	"	"	"

The next to the last is the average of a number of Cornish engines, collected for this paper.

The last is the average of 18, given by the editor.

Fowey Consols 80 in.—exceptional—1.7 lbs. per horse-power per hour, gives 1,160,714, for consumption of 1 lb. of coal, or 130,000,000 for 112 lbs.

Rowan's engine—exceptional—1.12 lbs. per horse-power per hour, gives 1,767,857 for 1 lb. of coal, or nearly 198,000,000 for 112 lbs.

After all that has been written about duty, in the January and August numbers of the "Journal," for 1869, engineers, and other scientific men, will be as much astonished as I am, to find that most Cornish engines, of the present day, are very poor machines, and that several other classes of engines are superior; amongst them the much abused marine engine, which does the same amount of work with about one-half the coal consumed by the Cornish engine.

There is every reason to believe that if all attending circumstances were noticed, and given due consideration, neither Rowan's engine nor the Cornish engine would have shown anything like the duty accredited to them. It is impossible to accept the belief that engineers of our day, in spite of their advances in scientific knowledge, are incapable of building a good pumping engine, and it is far more probable that these high duties are the results of very short, and imperfectly constructed, experiments. It must be remembered that there is a limit to the ability of steam to do work, even allowing it all that is claimed by Mariotte.

THE CRASH OF THE GUNS.—An amusing incident occurred at Portland on the occasion of the reception of the Peabody funeral fleet. Snow and sleet had fallen the day before, followed by rain during the night. In the morning the double-turreted monitors, *Terror* and *Miantonomah*, presented a beautiful appearance under the rays of the sun. Ice had formed two inches thick upon the stays, guards, flagstaffs, hurricane decks, turrets, and chains; icicles were pendent from the 8,000 square feet of gratings which form the hurricane deck. At the first fire of the heavily-charged 15-inch guns, the whole mass of ice came down with a crash upon the heads of the officers and men. The windows in the pilot-houses breaking at the same time, frightened the Portland pilots so badly that they sprang from the pilot-houses to the guys, slid down some 40 ft. to the decks, and took to their boats, under the impression that the monitors were sinking.

LEAD MINES OF MISSOURI.

From "The Iron Age."

The St. Louis "Journal of Commerce" recently published an article upon the lead mines of Missouri, to which we are indebted for the facts and figures here given. It says: Unfortunately no provision has been made to secure facts and statistics as to the present number of mines being worked, miners employed, nor the yield of different mines. Hence, we can only refer to statistics collected some years ago, as to the annual product of some of the largest and oldest mines."

There is probably no country in the world so rich in lead as Missouri. In the report of the State Geologist, made some 15 years ago, it was stated that there were "more than 500 localities, old and new, that promise good returns to the miner." What the number is now can only be conjectured, but it is safe to presume the number has more than doubled, as new discoveries are being constantly made. At different times, since the close of the war, lead has been discovered (partly by miners and prospectors, and in part by new-comers, while improving their newly-settled lands), which discoveries extend from the southwestern lead field eastward, through the counties of Lawrence, Barry, Christian, Stone, Taney, Webster, and into the edges of Wright, Douglas, Ozark, and Texas counties, thus greatly enlarging the area of country known to be underlaid by lead-bearing rocks. The State Geologist reported: "We have not examined a single county south of the Osage and the Missouri without finding in it more or less of this valuable mineral." It may be safely concluded that nearly all the counties in Southern Missouri are underlaid by the lead-bearing rocks of our State. The Commissioner of Agriculture, in his report for 1868, says: "Lead is found in greater or less quantity throughout the metalliferous regions of Missouri; and it is asserted that in no part of the world is there so large an area of lead-bearing rocks, so uniformly disposed, so regular, so readily identified, or on so grand a scale."

Most of the mines which are being worked are shallow. At Granby the lead comes to the surface of the ground. At the mine of Price, Bray & Co., 2,000 lbs. of galena have been taken from a shaft which is only 10 ft. deep. The ore at Mineral Point is in some places 18 in. thick.

	Pounds of Lead.
Total yield of Perry's mine to 1854	12,000,000
" " Valle's " "	13,000,000
" " Franklin's mine from 1824 to 1854	20,000,000
Yield of Shibboleth mine in 1841	3, 00,000
Yield of Washington and St. Francois counties from 1841 to 1854	50.000,000
Annual yield of Washington county	3,000,000
Total " Virginia mine	10,000,000
Yield of Williams' mine in nine months of 1854	145,000
Yield of Frazer's mine in one month	100,000
" " in one week	50,000
Shipped from Selma alone, from 1834 to 1854	70,000,000
Annual average of all mines from 1840 to 1854	4,000,000

Receipts of lead into St. Louis for the past 9 years have been as follows:

Year.	No. Pigs.	Year.	No Pigs.
1861	115,259	1866	146,584
1862	95,800	1867	144,555
1863	79,823	1868	186,823
1864	93,035	1869	172,583
1864	64,500		

The stock of lead in that city at the close of the year 1869 was about 15,000 pigs. The product of Missouri lead mines for 1869 was about 172,638 pigs.

The lead is mostly a sulphuret. Out of 120 specimens of ore, 113 were sulphuret, 6 sulphuret and carbonate, and 1 sulphate. From 60 to 80 per cent. of the ore is pure lead. The gangue is generally sulphate of baryta. The ore is often found in magnesian limestone, or red clay, interspersed with brown hematite, pyrites, and ochre.

The contract for the construction of the bridge over the Schuylkill River at South street, Philadelphia, has been awarded to John W. Murphy for $770,000. The bridge is required to be constructed of wrought-iron, to have cast-iron piers in the river with stone abutments, arches of brick and girders of iron. Its entire length is to be 2,419 ft., the truss spans to be each 185 ft., with pivot draw giving an opening of 77 ft. on each side.

IRON BRIDGES.

From "Engineering."

From the introduction of iron bridges down to the present time, there has been a growing tendency on the part of engineers to increase the strength of the superstructure, not only with the view of providing for the passage of heavier rolling loads, but also of reducing the intensity of the normal strain upon the metal. In this respect the development of iron structures has pursued a diametrically opposite path to that of works constructed in timber or masonry. Should we wish to cite examples of heavy scantlings in roofs, we must go back to the middle ages, and those roofs would then be found associated with walls of very different proportions to those provided by the Metropolitan Building Act.

There must be some reason for this difference in the treatment of iron structures, and we think it will be found in the exaggerated estimate originally formed of the strength of iron. Early experimentalists derived their information concerning the strength of wrought and cast iron from the fracture of pieces of iron wire, and of castings, some $\frac{1}{4}$ in. thick, and in both instances we now know well the results so arrived at would be nearly double those attained in full sized structures. Again, iron was considered to be so trustworthy and uniform in quality, that it might safely be loaded with one-third of the breaking weight, although the timber used in connection with it would ordinarily be loaded with little more than one-twentieth of the same.

Whatever the reasons may be, the fact, at least, is indisputable, that for the last quarter of a century engineers have very generally adopted the system of making each succeeding iron bridge a trifle stronger than its immediate predecessor; and the result of these accumulated increments is that modern bridges are very weighty and expensive affairs. It is especially incumbent upon engineers, therefore, to bear in mind constantly the axiom that the true science of bridge building consists in making a sufficiently strong structure with the minimum expenditure of material, and that there is nothing necessarily clever in making a very strong bridge.

There is no good reason to suppose that the majority of existing iron bridges are not sufficiently strong for the requirements of future traffic. Some three years ago a slur was attempted to be thrown upon the new Westminster Bridge by the promulgation of a statement that passage was refused for the crank shaft of the Hercules, weighing, with the lorry, some forty-five tons. The origin of this false report was exposed in our columns at the time by a letter from the engineer, but it was again reiterated in the columns of a contemporary last week. As Mr. Page's explanation was perfectly satisfactory, the public will be quite content to leave the determination of the exact position of this renewed statement in the scale of *mistakes* to "Touchstone" himself. Mr. Page's summing up will probably be simply—*mentitur impudentissime.*

A load of forty-five tons upon four wheels only is considerably in excess of any weight yet imposed upon steel rails, and it is, we think, hardly a fair load for an ordinary macadamized road. The load to be provided for in French bridges, according to the recent memorandum of the Minister of Public Works, is sixteen tons upon four wheels; our own Government inspectors usually assume a weight of thirty tons in their calculations, but the unit strain is taken at a higher amount on this side of the Channel. Some of the bridges on the Liverpool Central Railway have to be constructed to carry a load of sixty tons upon four wheels—a distinction they enjoy from their proximity to the Mersey Steel and Iron Works.

We hope that the Board of Trade will not be incited by recent proceedings in France to swaddle English engineers with any additional restrictions as to the strength of iron bridges. Attempted generalizations invariably entail extravagance in some instances, and there is no necessity for the interference of the Legislature, as few will deny that our engineers enjoy the confidence of the public to at least as great an extent as ordinary Government officials.

THERE are now 12,000 windmills in constant use in Holland, for drainage.

THE WHITWORTH GUN.

From "The Engineer."

On the night of Thursday the 4th inst., Sir John Hay called the attention of the House of Commons to the proposed expenditure on the further competitive trial of the Woolwich and Whitworth gun. We gather from Mr. Childers' reply that, notwithstanding all that has been said on the subject, and the total failure of the Whitworth gun at Shoeburyness on Wednesday, March 3d, a competitive trial is actually to take place; and the utmost that the public can now expect is that the experiment will be reduced to the narrowest possible limits. Even under these circumstances we have reason to believe that about £30,000 will be wasted. So long a time has elapsed since Sir Joseph Whitworth's original appearance in public in the character of an artillerist, that it is, we think, worth while to recall to the minds of our readers a few facts in connection with his theories and practice. The subject possesses so much importance just now, that we feel little or no apology for reverting to it is necessary.

No one who cannot establish a good title has a right to claim assistance from the State in carrying out an invention. If the invention be intended to supply in one way a want already satisfied in another way, it becomes very difficult indeed to establish this title. Thus, before Sir Joseph Whitworth can legitimately claim aid from the Government in introducing his proposed gun, he is bound to show first, that his system of artillery is likely to prove very much better than that at present recognized by military and naval authorities as the best; or else, that being no better, or but little better, it is very much cheaper. The last claim may be dismissed at once without further consideration, for it is admitted on all sides that the proposed Whitworth gun and its projectiles must be much more expensive than the Woolwich gun and chilled shot and shell. Sir Joseph Whitworth, therefore, comes before the public weighted with the difficulty of showing that his system of artillery is so much better than the existing system that it is worth adopting notwithstanding its increased cost. Considering the bearing of such a proposition, we have first to ask ourselves, is the proposer trustworthy in the sense that he thoroughly understands what he is talking about? Secondly, has he tried the system at all, and if so, with what results? And, lastly, how far are the principles on which the system is based likely to conduce to the result which it is stated can be obtained from its adoption? Even Sir Joseph Whitworth himself will admit that the nation called on to spend large sums in testing his theories for truth or falsehood, is entitled to weigh these present theories by the theorist's past practice, especially so because the Whitworth system of rifling, etc., is not new.

In dealing with the first of these problems, we must bear in mind that Sir Joseph Whitworth knows nothing practically of actual warfare. This is, perhaps, but a small matter, but it is worth noticing. In the second place, he is, of all men living, the least likely to lend himself to the production of instruments of warfare of the rough-and-ready class. Such things are, to him, utter abominations. He has achieved, and deservedly, a world-wide reputation as the most accurate mechanician in existence. His machine tools are absolute marvels of perfection; and this reputation and perfection result from the peculiar constitution of the man's mind. He is fastidious to the last degree in mechanical matters, and this fastidiousness, in its proper place, has produced the happiest results. But in actual warfare exquisite refinements of mechanism are absolutely out of place, and we maintain as a consequence, that Sir Joseph Whitworth is not—judging of him by his mental calibre—a man likely to supply our fleets and our armies with ordnance fitted to withstand the exigencies of modern warfare. In other words, he is about the last man to whom we should think of applying for a gun which would stand, as a good gun must, all sorts of service. So much for the first point. Let us now see how far his past practice supplies us with reason for hoping that Sir Joseph Whitworth is able to give the nation a better gun than it now possesses. Strange as it may sound to those who, like ourselves, are admirers of Sir Joseph Whitworth's genius, it is nevertheless true that his entire career as an inventor of small-arms and ordnance

has been marked by a succession of failures. That his successes have been numerous is also true; but every one of his successes depended on the presence of conditions many of which would be secured in the practice ground, few or none on the battle-field. He first came before the world at large with the Whitworth rifle. Government made him a grant of £15,885 to work out this invention.* The new weapon shot as rifle never shot before. It enjoyed an ephemeral reputation, which lasted just until the rifle was put to something like service. The use of the Whitworth small-bore rifle is now confined to the Rifle Brigade and the 60th Rifles, as far as the British army is concerned. All the Whitworth rifles in the Tower—in other words, our entire reserved stock of these weapons—have been advertised for sale. No foreign Government, to our knowledge, has adopted the weapon at all, the use of which is now practically confined to match shooting. Next came the Whitworth big gun. This, too, enjoyed a reputation of a sort. Mr. Whitworth was, we believe, the first to drive a shell through an armor-plate. His gun was thought to be very accurate, and he got no small number of orders; yet we are justified in stating that the Whitworth gun never yet gave satisfaction in actual warfare. About the first really severe test which it underwent was at the siege of Charleston, during the last American contest, seven years ago. The Federals possessed two 80 lb. Whitworth rifles, from which they expected great things. They became useless after firing less than 120 rounds each. From the report of General Turner, Chief of Artillery during the siege operations, we learn that the Whitworth guns first opened fire on Fort Sumter with shells at 4,000 yards' range. The use of shells had almost immediately to be abandoned, owing to their premature explosion, which seriously endangered the Federal troops in the advanced trenches. Only solid shot were then used. We quote General Turner's report as to the performance of the guns with these projectiles, as given in General Gilmore's "Engineer and Artillery Operations against the Defences of Charleston Harbor in 1863." General Turner writes: "There appeared to be much difficulty experienced at times in loading these guns by the projectile wedging when part way down. It could then be rammed home only by heavy blows by a handspike, or by attaching a powerful purchase. They were very unsatisfactory in point of accuracy, shooting very wildly, seldom hitting Sumter at 3,980 yards. In comparison with the 8-in. Parrot guns in the same battery, they fell short in accuracy, and subsequently one of them became disabled by the gun apparently sliding through the reinforce. The other being considered unsafe after this, its further use was discontinued." We have here a record of not one, but four failures. In the first place, the gun could not be used for shell firing; in the second place, it could not be depended upon to hit what it was fired at; thirdly, it was loaded with the utmost difficulty; and, lastly, it could not be fired at all. On every conceivable point the Whitworth system failed before Charleston in 1863. It may be urged that many improvements have been effected since then. To find out whether this is really the case or not, we must turn to later tests; of these we have two—one in the performance of the gun in the Brazilian war, the other in its performance at Shoeburyness. The Brazilian officers report dead against the Whitworth gun. It was impossible to load it after a few rounds, although the most extraordinary devices were used to keep the bore clear, even to bringing a hose from the boilers of the steam ships engaged, through which hot water was forcibly blown into the gun after each discharge. Even with this, many times over the gun had to be fired with the shot not home. It is said that the powder was bad and fouled the gun, but this is no excuse. If the weapon is not able to get on for a couple of days, burning bad powder with no worse result than reduced range, it is not fit for actual warfare. But tested in the practice ground, Sir Joseph Whitworth's system did not do better than it did in Brazil. The Ordnance Select Committee reported against it in 1861, after experiments which cost the nation £10,278; and the last and best gun that Mr. Whitworth has made failed lamentably at Shoeburyness on Wednesday the 3d instant. It shot so wildly that at 200 yards range the projectile never went near the point aimed at. The projectiles, made of the new and professedly

* The hexagonal rifle was invented by Mr. Brunel, not by Mr. Whitworth.

tough metal, went to pieces when in the form of shells—one breaking up on striking the target, to which it did little harm; while the other went to bits in the gun. The second shot of the three fired was, indeed, tolerably successful, but only because Sir Joseph Whitworth had borrowed the ogival head from Major Palliser. Indeed, he had not on the ground one of those flat-headed punching bolts which were intended to do such wonders against oblique or any other targets. His so-called "flat-fronted" shot is simply Palliser-shaped shot with the ogival head truncated. Finally, we cannot find that a single nation of any importance has adopted the Whitworth gun, or having tried it speaks favorably of it. And yet this system, whose history is a record of failures, is to be put into competition, at a great expense, with guns which are admitted, by the very gentlemen who propose the test, to be "perfectly satisfactory."

We shall now consider, as briefly as possible, how far the Whitworth system appears to possess the qualifications necessary in a good gun. The Whitworth gun about to be put before the world is peculiar—first in respect to its rifling, secondly in respect to its material. The rifling will be of the well-known hexagonal type, the projectiles of great length, and machined to fit the bore. We really believe it to be impossible to devise a form of gun more likely to foul than this; or, in other words, a gun the minimum quantity of fouling in which can do more mischief. As to easy loading when in service, that is not for a moment to be expected, unless some device is introduced which has been hitherto wanting in all Whitworth guns. Then, be it observed, it is part of the system that the gun should be of small bore, though the projectile is very heavy. In order to acquire sufficient initial velocity, therefore, Sir Joseph Whitworth uses the strongest rifle-powder he can get; and not only this, but a tubular cartridge specially designed to secure the burning of the powder with the utmost speed; and this, be it observed, just at the time when we are beginning to use pellet powder to spare our guns some strain. But even with this the initial velocity is less than that of the service guns firing an equally heavy projectile. Is there in all this any reason to conclude that the system is likely, on theoretical grounds, to prove satisfactory? If there be, we confess it has escaped us. Lastly, we have the new metal to deal with. If it can be shown that this metal is really better than any we have got now, then by all means let us have it; far be it from us to say that because the Whitworth system of rifling fails, Whitworth metal must be bad too. But what is Whitworth metal? All that is generally known is that it is steel cast under compression (we shall have something more to say on this point at another time), and that the projectiles made of it and fired the other day at Shoeburyness behaved much as the worst cast-iron that could be found would have done. We are told, by way of excuse, that it is very difficult to temper Whitworth metal, and that the shot and shell which failed, did so because they were imperfectly tempered. If such difficulties are encountered in the process, that one projectile out of three must be deemed a failure, we presume that, as the guns must be tempered too—and they are much more difficult to deal with than shot or shell, because they are bigger—not more than one gun out of three will be a success.

Even the "Times" begins to show signs of deserting Sir Joseph Whitworth. Will some of his friends come forward and vindicate his system of rifling and his new metal from the charges brought against both, or are we to assume that the case is so bad that nothing can be urged in favor of one or the other?

Bessemer Steel Making in France.—The total production of Bessemer steel rails in France in the first six months of 1869, amounted to 19,755 tons, against 10,562 tons in the corresponding period of 1868; it is probable that the French production of this description of rails will show a still further advance in the second half of 1869, as large orders have been given out during the last two or three months by the great French railway companies. Among the more recent orders of steel rails, we may mention one for 2,000 tons, given by the Orleans Railway Company to the Creusot Works, at £11 7s. 2d. per ton, and another for 3,000 tons, given by the Western of France Railway Company to the Terrenoire Works, at £11 10s. 3d. per ton.

ELASTICITY IN THE TRACK AND ROLLING-STOCK.

From "The American Railway Times."

No matter how perfect the track and superstructure may be, the more perfect the elastic system of the rolling stock, the better it is for both. The true secret of the success of many of the ill-built American railways is in the elastic character of the rolling-stock; by this we mean the arrangement of springs for taking up the shocks at the many uneven points at the track, and the flexible character of the rolling-stock, enabling it to pass curves easily. The general character of the road-beds in this county is far below that of the prominent roads in Great Britain and on the Continent. The larger and better roads there approach perfection; that is, they are smooth and straight in comparison with American roads, so that engines and cars with little elasticity and long wheel-base are run with very good results. The same rolling-stock put upon American roads would pound itself to pieces very shortly. While foreign engineers have made the character of the road-beds a matter of the first importance, the Americans, by the bad character of theirs, have been compelled to pay more attention to the elastic principle in the rolling-stock. The Americans can well imitate their foreign brethren in the excellence of their road-beds, and they, in return, pay as much attention to the elastic principle in rolling-stock. The nearer they both approach perfection in both respects, the longer "life" is insured to both the track and rolling-stock. A gentleman informs us that he has often ridden over a Prussian railway, in a car 30 or 40 ft. in length, with hardly any springs, and though the movement was hard and rigid, yet it was very smooth, while the expenses of road-bed repairs were very small compared to those of this country. Such a road-bed as that, with the better class of American rolling-stock, would seem to approach perfection in railway travel, giving the maximum of comfort to the traveller, and the minimum of expense in operation.

Starting with a well-drained and well-ballasted road-bed, laid with a rail stiff enough to allow no deflection between the sleepers, or at the joints, and add to this rolling-stock, arranged to take up the concussion from all vertical or horizontal blows resulting either from slight obstructions on the rail or a possible defect at the joint, or from sharp curves, and it would seem that the combination is as near perfection as is possible with our present ideas of the allowable cost of railway construction. The devices for securing the requisite elasticity in the track are many. In the first place we rely upon the ballast and the wooden cross-tie; then again chairs are packed with wood or rubber, or some other material more or less elastic. All these are very important, slight as they may seem to the uninformed. Then, in the rolling-stock, there are many devices for taking up the sidewise or lateral motion at high speed; then in passing curves we have Fairlie's device, enabling engines of long wheel-base to pass curves of very sharp radii, and Bissell's and Hudson's arrangements for the same object, both of great value; then for Tenders, we have Bissell's device, allowing entire flexibility between the back and forward trucks so that all abrasion or crowding of the wheels against the rails is prevented even in the sharpest curves, giving longer "life" to wheels and axles, and much greater ease in carrying the load. Grigg's Elastic Wheel, for both locomotives and cars, is another very important improvement, saving the wear of wheels, tyres, and every other part of the rolling-stock. The well-known swing-beam device in long passenger cars is another standard improvement of great practical value, so far as comfort or economy is concerned. So far as we can apply elasticity and flexibility without destroying the requisite steadiness of movement, we are proceeding in the right direction, saving at the same time the road-bed, superstructure, and rolling-stock, and are in fact obeying the true mechanical and natural law.

A BRASS door, weighing 1,456 lbs., and costing $850, has recently been manufactured in England for the Wolf Rock Light House. It is intended to replace a solid oak door, four inches thick, which had been shattered into fragments by the force of the waves.

MASONRY: DESIGN AND CONSTRUCTION—THICKNESS OF MORTAR-JOINTS IN MASONRY AND BRICK-WORK.

From "The Builder."

The following remarks were commenced in reply to a question in the "Builder" as to the advantages, or otherwise, of thick or of thin beds of mortar. They have been extended.

The quantity of mortar which may safely and with advantage be used with bricks, must in a great degree depend upon the quality of the mortar, and the purpose to be served by the brick-work. Some mortars swell (expand) in use; others shrink. The best samples of mortar in setting become hard and tough; poor samples remain soft, and crumble on exposure. A thin bed of the best mortar for such a work as a tall chimney would not be so strong as a thick bed, because in a thin bed there will be parts where the best bricks will be in contact, even where $\frac{1}{8}$ in. thickness of bed may have been specified for, and this thickness of bed and joint may show on the face of the work. With common bricks, a bed of $\frac{1}{4}$ in. of mortar will leave rough projecting portions of the bricks in contact. Good mortar, when set, is, as we have just said, hard and tough; and to secure the whole strength it is capable of giving, the entire bed and joint must be full, so that the whole area of beds and joints of bricks shall be cemented by intervening mortar. Bricks and tiles of the best kinds, and mortar as composed and used by ancient Roman builders, appear to be indestructible under any ordinary action of the elements. Samples of Roman masonry—rubble and brick-work—occasionally dug up in London, and at other Roman sites in England, do not show any signs of decay, and in Italy entire structures remain sound and firm, with the exception of mutilations purposely made, wantonly or during war, in attempts to utterly destroy them. In these old works and ruins the proportions of mortar are usually about one-third, and sometimes one-half. The best rubble-work now consists of one of mortar and grout to three of stone, and the soundest rough brick-work, as in bridge abutments and retaining walls, one of mortar and grout to four of bricks. There are arches of Roman work constructed of flat tiles set in beds of mortar almost, if not quite, as thick as the tiles, and those structures which have been destroyed by man (probably in war) show sound fractures and materials undecayed.

The strongest work at the Liverpool docks is the granite rubble, consisting of one of mortar and grout to three of stone. The late Jesse Hartley, during the last twenty years of his life and practice, constructed dock and river walls of granite rubble masonry. The first twenty years he used ashlar masonry, hewn to an exactness and truth such as no other engineer ever obtained; the blocks of stone varying from 20 cubic ft. up to 200 and even 300 cubic ft. These blocks were set, stone and stone, over the entire areas of beds and joints, the backing being rubble. It is, however, the rubble backing which gives strength and endurance; and this will be sound when the ashlar has been crushed, or has decayed.

If these remarks are read by any young architect who wishes to construct cheap, sound, and enduring works, we recommend rubble to his notice for heavy masonry works, and brick-work thin, hard, and well-burned bricks, set in thick beds of good mortar. Even for public buildings the rule holds good, as at Windsor Castle, where the rough-faced wall stones are set with thick beds and joints of good mortar, stuck with spalls of flint. Compare the resistance of this work to atmospheric influences with the masonry at Westminster in the Houses of Parliament. The walls of Windsor Castle will be sound, in their rough strength and beauty, long after the elaborately-carved stone-work of the Westminster Palace has mouldered away. The cost of the two sorts of masonry is very different, probably as one to five, and in some cases one to ten—the rough work being, of course, the cheapest.

With regard to masonry and brick work construction generally, very much more more may be said, and especially about design. The "five orders" continue to be the alphabet for one set of architects: Gothic is the style chosen by another set, the Rennaissance and the Elizabethan style of architecture influencing others. Our

modern club-houses, public offices, and private residences give us rusticated basements, windows with pediments beneath string-courses, and heavy cornices which bolts and cramps can only keep in place. Columns should have something to support which could not otherwise be supported. Pilasters should give strength where it is required; pediments, string-courses, and cornices should act as protections from the weather, and ought not to be present where it is impossible for this purpose to be served. Rusticated ashlar masonry is not necessarily stronger, by reason of the amount of projection given to the face, as the true strength is in the breadth of bed, truth of workmanship, and in the care and mode of setting. If the breadth of bed to ashlar masonry is cut away to form a deep rustic joint, then is the work so much weakened by the process. With respect to design and construction in masonry, will one architect consent to design a public building in an original manner, regardless of all example and precedent, and not use one moulding or ornament which does not grace construction and is useful? Let him think over the purpose or purposes to be served by plinth, rustic, column, pilaster, architrave, pediment, impost, arch, key-stone, balustrade, string-course, cornice, and every other detail, and discard one or all if plain work will be sufficient. Ample scope for ornament may be found in the useful, and it will then be discovered that economy and power of endurance are on the side of that which is useful, and also that consistent decoration is most beautiful. Masonry will then be in keeping, as there will be harmony and breadth. Old Lambeth Palace, consisting of rubble, shames florid structures in endurance; and the noble massing and fine outlines of Windsor Castle would not be improved converting the walls into finely-tooled or polished ashlar masonry. London smoke, dust, and dirt soon disfigure hewn ashlar, which is deeply rusticated, and elaborately moulded; and carved masonry, such as that executed at the new Houses of Parliament, must inevitably and rapidly decay. The Windsor Castle coursed wall-stone is dirtied, but is not decayed as hewn moulded and carved masonry is. Thin courses of hard wall-stone and thick beds of good mortar last longest, even in palaces and in churches.

WASTE OF LABOR IN BUILDING.

From "The Scientific American."

Of all the painful sights we are called upon to witness in this day of steam engines and labor-saving appliances, none strikes us as being so absurd and unnecessary as the waste of human toil in building as it is generally conducted. Hod men crawling up long ladders with small burdens of bricks and mortar, carrying at each trip some sixty or seventy pounds of building material, with thirty or forty pounds of hod, and one hundred and sixty or more of flesh and blood—not to mention beer—seems something so foreign to this age of machinery that we should scarcely feel it more incongruous to see the stocks and pillories restored to our market places.

If a huge beam or girder is to be raised, we see the crane, tackle, and steam-engine employed, but the ordinary carrying is done by human legs. These legs, although they can do climbing passably, are certainly inferior in this respect to other legs designed by nature to make climbing a specialty.

A ladder is a very serviceable appliance in its way; we, however, believe it to be as hard a road to travel as ever the genius of man devised. The hod belongs to an ancient and honorable family of implements, but it does not seem the most agreeable companion in the world to clasp in affectionate embrace or place one's cheek fondly against.

Therefore we say, down with the hod; let it take its place with the host of implements, on the tomb of which modern progress has written the epitaph—"PLAYED OUT."

Let us suppose the two side pieces of a ladder to be replaced by iron rails and the rounds by ties, and let us suppose some genius to conceive the happy idea of causing a locomotive to crawl tediously up this heavy grade, drawing after it a load of one third its own weight. What gibings,

what laughter, what derision would such a scheme excite among mechanics! Yet we are importing annually large numbers of locomotives to do the same thing; only these locomotives run on the ties instead of the rails.

They do these things better in France. Either derricks are employed, or the brick and mortar carriers are used as stationary engines, rather than as locomotives. In passing a building in process of erection in Paris, one may often see a number of men stationed one above the other along a ladder, each of whom passes his load to the next above him, until the load reaches its destination. In this way a continuous procession of materials is kept up, and a large quantity may be elevated in a short time.

This is an improvement on the climbing process, but there must even in this way be an enormous waste of power. And this waste is not only useless, but so easily avoided that the continuance of the employment of human power to perform such rude work is a disgrace to modern civilization. It can be demonstrated that a small one-horse power engine, with suitable tackle, and the employment of a single man to attend it, will do the wo·k of six men at elevating bricks and mo·tar, at a cost of less than the wages of two men.

No mechanic who reads this will fail to see many ways in which this application of steam power could be advantageously made. The ladder might be replaced by a railway up and along which a car-load of bricks or mortar might be made to roll, which track might be joined to and made continuous with a horizontal track, by means of an easy curve at the summit, the whole being adjustable to suit the progressive heights of the wall as they advance towards completion. It would require little genius to adjust the detail, and the cost of building would be greatly lessened by dispensing with the hod-carriers.

THE HARVEY TORPEDO.

From "Engineering."

The development of the torpedo as a weapon of naval warfare received an impetus from the practical results of its use in the American war. Since that time many improvements have been introduced in its construction, and all the refinements of modern science have been called into requisition to render it as sensitive and as deadly as possible in its operation. The question is one in which all maritime nations have taken a greater or less interest, and we have from time to time recorded the results arrived at now by this foreign power, and now by that. America has been busy perfecting a system of torpedo boats and gear, which is reported to be very complete and efficient. In Austria the authorities have been carrying out a series of experiments in the same direction with a self-propelling, self-guiding submarine torpedo, worked by compressed air, the performances of which are stated to have been as satisfactory as they were extraordinary. Russia has taken up the question in a practical manner, by sending a commission to England to investigate the merits of the Harvey torpedo, which proved so satisfactory that that weapon has been adopted into the Russian service. These unmistakable signs of activity in providing for this kind of warfare have at length roused our authorities at home to a sense of the necessity of at least no longer remaining behind other nations in this respect. So it comes that they have recently instituted a series of searching experiments with the Harvey torpedo, which forms the subject of the present notice. The inventor of this weapon is Captain John Harvey, R. N., who has for years past endeavored to convince the Government of the absolute necessity of having an arm of this description, which should be at once effective and reliable in working, and handy in use. The authorities, however, remained perfectly indifferent in the matter until they found a foreign power preparing to arm itself with Captain Harvey's invention. The necessity then became obvious, and they forthwith instituted inquiries, and directed experiments, which have proved satisfactory, and which we believe will lead to its adoption in the British service.

Captain Harvey's torpedo consists of a stout wooden casing, strengthened on the

outside with iron plating, and containing a metal shell which holds the powder charge. A central transverse section of this case shows a rectangle; in plan it is a rhomboid, the ends being angled to give the torpedo, when towed, a divergence of about 45 deg. from the vessel towing it. The movements of the torpedo are controlled from a vessel specially constructed with a view to great speed, and so arranged as to render the action of the enemy's shot, when bow on, of but little consequence to her. The form of the torpedo, and an arrangement of slings in connection with it, enable the operator to diverge the shell alongside the enemy's ship in meeting, passing, or crossing, whichever method of attack is adopted. The torpedo is fitted with a very simple arrangement of outside lever, acting upon an inside discharging apparatus; the explosion being effected when the weapon is in hugging contact with the enemy's vessel. The shape of the shell insures a large amount of surface in contact with the ship's side when exploded, whilst at the same time it offers very little resistance in towing. The depths of immersion of the torpedo below the surface of the water can be regulated by the speed of the vessel towing it. A buoy is attached to the apparatus, which is of sufficient displacement to support the shell at the extreme depth required, and also to recover the shell if necessary. A safety key is fitted which relieves the operators from all fear of accidental explosions, as until this key is withdrawn the exploding apparatus will not act, and the key is never withdrawn until the shell is some yards astern of the torpedo vessel. The size of the shell varies with the amount of the explosive compound it is intended to carry, the ordinary quantity being about 70 lbs. of powder. The explosive agent used is known as Horsley's powder, a most violent fulminate composed of chlorate of potassa and gall-nuts in proportion by weight of three to one. The ingredients are kept separate, and are mixed in sieves at the time of use; they form an admirable charge for the torpedo, the disruptive action of the powder in relation to the best gunpowder, volume for volume, being something like 15 to 1.

Such is the Harvey torpedo and its charge, and it was with several of these shells—uncharged, of course, but fitted with the exploding bolt—that a series of experiments were recently carried out at Portsmouth by direction of the Admiralty. The Camel steam tug was used as a torpedo craft, and was fitted with the necessary paying-out apparatus, which is provided with simple but powerful friction brakes. Captain Harvey conducted the operations from the Camel against the Royal Sovereign converted turret ship, which was in command of Captain Boys, R. N., of the Excellent, and who had charge of the official trials. The object of the Camel was, of course, to strike the Royal Sovereign with the torpedoes, the latter doing her best to avoid being struck. In the first part of the operations the Royal Sovereign remained at anchor, the Camel towing a 76-pounder torpedo with 50 fathoms of line at an angle of 45 deg. from her wake. The speed of the Camel was about 8 knots an hour, and under these conditions 10 attacks were made upon the assumed enemy. In every case the torpedo struck the Royal Sovereign at depths of from 1 to 16 ft. The position of the Camel was varied each time; sometimes she was right ahead, sometimes right astern, and at other times crossing. In order to estimate the chances of ridding herself of the Camel, the Royal Sovereign opened fire from her turrets. In two instances during the attack she fired 4 and 7 shots respectively, but in each of the rest she never got off more than 2 rounds. After each trial the working parts of the torpedo were examined, and it was found that in every instance the exploding bolt had acted. The safety key was withdrawn at distances ranging from 8 to 60 yds. from the Camel with ease and unvarying certainty.

The Royal Sovereign got under weigh for the second series of attacks, which were made with the Camel steaming at about 11 knots, the Royal Sovereign running at a speed of from 8 to 9 knots. A torpedo was carried from each quarter of the Camel, with 50 fathoms of tow line, and a divergence of 45 deg. in each case. A series of well-executed manœuvres were intended by Captain Boys to place the Royal Sovereign beyond the reach of the torpedoes. He could not, however, elude the Camel, and in the 6 trials made, every torpedo invariably struck the adversary. The points of contact varied, as before, from 1 to 16 ft.; 2 struck directly under

the ship's bottom. The method of attack observed by the Camel varied as in the previous experiment; sometimes she came up from the stern, sometimes down from ahead, whilst at others she crossed the bows of the Royal Sovereign. The latter ship again tried the number of rounds she could fire during each attack, and these varied from 2 to 12.

The results of these trials proved the torpedoes to be perfectly under command, and thoroughly effective in action. One great feature of the torpedo is that all its arrangements are simple and sailor-like, and it is exactly fitted for the class of men within whose province it will lie to use it. The paying out apparatus and its brake arrangement are also readily worked by an ordinary seaman ; in fact, from first to last there is nothing that requires a specially experienced staff to work this torpedo. The manufacture of these weapons is carried out by Mr. Nunn, of St. George street, East, who has introduced several improvements into our marine signal lights, and who deserves credit for the substantial manner in which the torpedoes are constructed. We examined them after the trials and found several of them had been severely knocked about, showing the rough usage to which they had been subjected. They, however, still hung well together, although the iron plates were in some places ripped from the outer skin. One point demonstrated by the recent experiments ought not to be lost sight of, as it is of great importance, and that is, that if the torpedo is laid to a passing vessel, and she should prove to be friendly, her destruction can be arrested. This was effected by so managing the tow rope as that the torpedo cleared the approaching vessel. On all points, then, it seems clear that in the Harvey torpedo we have an efficient apparatus, well adapted to its special purpose, and possessing all the necessary requirements of such a weapon. The Government, having proved its merits, will, we presume, recognize them by adopting it into the service without further delay. It seems pretty clear that naval supremacy in the future will be with that maritime state which is the best practised in torpedo warfare, and which has a navy adapted to the service of the arm.

EQUILIBRIUM OF FLOATING BODIES.

Translated extract from "Exposé de la Situation de la Mécanique Appliquée."

The investigation of the action of a liquid or a gas on a solid body immersed in part or entirely, is one of the oldest problems of physics. Archimedes discovered its solution, and said : "Every body immersed in a liquid loses a part of its weight, equal to that of the fluid which it displaces." This statement is not rigorous, and every day gives rise to some misconception. It is one of the resources of those who attempt to invent perpetual motion. An inventor, for example, will refer to the principle of Archimedes in maintaining that a massive cylinder, movable about an axis supposed to be horizontal, and forming the lateral wall of a vessel entirely filled with water, tends to turn indefinitely upon itself without expense of liquid ; because the part submerged in the water loses a part of its weight, while the other part maintains its total weight. If, instead of this misleading conception of a loss of weight, the inventor would think of the forces exerted by the water upon the cylinder, he would perceive that they are all directed towards the axis of rotation, and that they could have no tendency to set the cylinder in motion. The principle of Archimedes must then be suitably interpreted; and had it at first been announced with strict scientific rigor, it would not have so numerous a brood of illegitimate offsprings clinging about it. It can be asserted that out of ten projects of perpetual motion, there are seven or eight whose authors refer to Archimedes, thinking that they have found an incontestable support in his famous principle.

The problem of the stability of equilibrium of a body immersed in a liquid, presents two distinct cases— one very simple, in which the whole body is submerged ; the other much more complex, that in which the body floats on the surface of the liquid. In the first case it is necessary to equilibrium that the weights of equal volumes of the body and of the liquid

should be equal, and that the centre of gravity of the body, and that of the displaced volume, should be in the same vertical; for stability, it is necessary and sufficient that the first of these two points should be below the second.

In this case the resultants of the action of gravity, and of the forces from the liquid, have definite points of application, which remain fixed in the body when its position is disturbed. A body entirely submerged is in a condition like that of a heavy body suspended by a thread. In considering the second case, that in which the body floats and is partially sunk in the fluid, we still perceive that the weight of the body is equal to that of the fluid displaced by the submerged part, and that the two centres of gravity—that of the body and that of the displaced fluid—are situated on the same vertical line. But the question of stability becomes more intricate. If a sufficiently small displacement is given to the floating body, this generally modifies the form and volume of the displaced liquid so that the point of intersection of the resultants of the forces, —the point which may be called the centre of careening—does not maintain a fixed position in the body. The body cannot therefore be considered as suspended by a thread attached to a definite point. To carry out the simile, it would be necessary to consider the point of attachment as movable in the body; which does not give a clear conception to the understanding.

In a practical point of view the problem of the stability of a body was solved long ago, for navigation supposes the solution known; and from ancient times vessels of sufficient stability have been constructed. But it was not till the 18th century that an attempt was made to establish a theory. The first, due to Bouguer, very ingenious but not sufficiently general, depends upon the consideration of the *metacentre.** The metacentre has an exact definition only in the case of a floating body which has a vertical plane of symmetry. If this plane of symmetry receives a slight displacement, under the condition that the immersed section remains constant, the centre of buoyancy will describe an element of a curve perfectly determined. The metacentre is the point in which, after displacement, the vertical drawn from the new centre of buoyancy cuts the position taken at the same instant by the straight line containing the only centre of buoyancy and the centre of the body. It is, in other words, the centre of curvature of the locus described by the centre of buoyancy in the very small displacements impressed upon the body under the specified conditions. That the equilibrium may be stable it is sufficient that the metacentre should be above the centre of gravity. If the body has two planes of symmetry, a particular metacentre corresponds to each; and it is necessary to stability that the lower of the two should be above the centre of gravity of the body.

This theory, it is obvious, is very incomplete. It supposes that the floating body has a plane of symmetry. Indeed, if we attempt to apply it to a body not having a plane of symmetry, or if, supposing the body symmetrical with reference to a plane, the position of the metacentre for a displacement not parallel to that plane is sought, it is defined by the directions of two lines which do not intersect. Even if the displacements are restricted to those which are parallel to the plane of symmetry, an infinite number can be imagined; yet the theory considers but one. It therefore reduces the generality of the problem, by an arbitrary choice of the only displacement in which the transverse area of the buoyant volume remains the same. Now, if it is wished to rid the investigation of this arbitrary limitation, an infinite number of possible positions for the metacentre are found, of which some may fall below the centre of gravity without causing the equilibrium to become unstable. The theory of the metacentre is, therefore, incomplete, and depends upon a course of reasoning which, if literally applied, may lead to error.

We now have a theory which seems preferable, because it has a much more extended generality. It is known that the discussion of the equation of living forces helps to determine the stability, instability, or conditional stability, of a system in equilibrium. It is, then, a return to general and rational methods to apply this equation to the investigation of the conditions of stability of a body floating on the surface of a liquid. M. Duhamel has developed this method. A floating

*Bouguer, "Construction des Navires," 1746.

body being in equilibrium, he supposes that infinitesimal velocities are impressed upon it; the body is consequently animated with a certain living force, upon which the work of external forces acts, either to increase or diminish it. The question reduces to the determination of the variation of the work of exterior forces as determined by the displacement of the body. In these forces M. Duhamel represents only the weight of the body, and the hydrostatic pressures of the liquid. The discussion of the signs of the terms of the equation of living forces serves to distinguish the cases in which the initial displacement can receive finite increments from the case in which the displacement of the body remains limited. The last case is that of stable equilibrium; the formula which gives this condition is, strange to say, the same which the theory of the metacentre would furnish in the restricted cases in which it is applicable. So the use of the equation of *vis viva* justifies, not the reasoning, but the results obtained by a coarser method. It is the rigorous demonstration of a rule discovered by a kind of divination, and afterwards verified by long experience.

Is the theory of M. Duhamel itself complete; and is the subject of the stability of floating bodies henceforth exhausted? Far from it. We have already mentioned that M. Duhamel, in this respect following the hypotheses of the theory of the metacentre, admitted into his equation only the static pressures of the liquid. This point of view is not sufficiently general; for it is a contradiction, to impress upon a floating body certain velocities, and to treat the mutual reactions of the body and the liquid as if the relative repose of the two systems had not been disturbed. The imperfection of the theory is perceived when we wish to determine the exact laws of the oscillation of floating bodies, but the investigation of the conditions of stability seems not to be seriously affected by this imperfection. It seems evident that the movement of a body in a fluid mass cannot but develop resistances of friction, whose work tends to reduce the living force of the moving body; if stability is assured without taking into account these various resistances, it is certainly so *a fortiori* when they are introduced into calculation. Experience confirms this estimate, for it shows that stability never has failed in vessels built according to the usual rule.

The question is, therefore, entirely solved in a practical way, without being so in a scientific point of view. Among the recent efforts to complete the theory, we cite the labors of M. Reech, which will give to the old theory of the metacentre a more rigorous character; those of M. Jordan and those of M. Clebsch, who has attempted to complete the theory of M. Duhamel by the introduction of the dynamic resistance of liquids. Viewed in this general manner the problem presents difficulties which have not yet been surmounted, and really belongs to the obscure domain of hydrodynamics.

THE MANUFACTURE OF COKE.

From "La Houille."

Coal is composed of carbon (the largest element) and condensed oxygen and hydrogen, mixed with a greater or less quantity of earthy matter. It also contains a very small proportion of azote, which, by distillation, produces ammonia water. Coal is not a compound of an invariable character, but a mere mixture of the above elements in very different proportions. It could not be otherwise, being, as we have said, only a mixture, and because in its geological formation it is like turf. We have tried more than two hundred samples of coal of all kinds, and we have never found two alike, unless they came from the same mine, and, in fact, from adjacent points in the same seam.

The proportions of earthy matter have an almost infinite variety; carbon, oxygen, and hydrogen vary only between certain limits. It is the relative proportions in which these elements are found which give to different coals their distinctive characters, and which determine the particular purpose for which they are employed in industry.

In different kinds of coal, oxygen forms a proportion of from 3½ to 17½ per cent.;

hydrogen from 2½ to 6 per cent.; and carbon from 77 to 94 per cent.

In rock of more recent formation than coal rock, mineral combustibles may contain these elements, and especially oxygen, in much larger proportions. Carbon may constitute a proportion of 96 per cent., hydrogen 9½ per cent., and oxygen 37½ per cent.

But neither by calcination nor by distillation can we obtain as a fixed product the whole of the carbon; there is always a certain part which escapes in the form of volatile matter combined with hydrogen. Calcination with different coals, the crucible being employed, gives from 55 to 93 per cent. of fixed coke, and from 7 to 45 per cent of volatile matter.

Coal may be *meagre* (that is, not forming one consistent mass or giving coke when heated in a crucible, an oven, or a retort) from three different causes: (1), by excess of carbon, as in the case of anthracite; (2), by excess of oxygen, as in the case of certain free-burning coal of the Saône-et-Loire and Sarrebruck coal-fields, which contain more than 17 per cent. of oxygen; (3), by excess of earthy matters.

The more the hydrogen element predominates the more bituminous the coal.

By slowly distilling the different kinds of coal (in a glass retort for example), we may obtain bitumen varying from the very smallest appreciable quantity to 16 per cent. of the whole substance (leaving out of the question a few rare and exceptional varieties which contain a still larger proportion). In regular coke ovens, then, the coal is distilled slowly, as in the glass retort, because it is operated on in large quantities, and the duration of the operation is thus not less that 24 hours.

It is bitumen which agglomerates the particles of coal during coking. Coal which gives no bitumen or scarcely any, as anthracite, cannot be converted into coke, even with the crucible, without the assistance of an admixture of more bituminous coal. That which gives a very small, or a small quantity of bitumen, is called *meagre* or *demi-meagre*. And, in this latter case, the small quantity which does exist is to be employed to the greatest possible advantage, in order to bring the particles of the coal together and make them adherent.

This object is only practically accomplished by submitting the coal to a very great and well-sustained heat, and by facilitating the union of the particles by the most suitable mechanical preparations.

By means of experiments with the crucible, we have observed the manner in which coal is converted into coke, and the necessity of very great heat in order to succeed in coking with *meagre* coal; and this observation of the process has aided us in our researches after proper means of facilitating this result.

When coal is submitted to a very great heat in a crucible, or compartment of an oven, the whole mass is not softened at the same time, nor is it at any given moment transformed into coke. On the contrary, the formation of coke takes place in a gradual and continuous manner, beginning from the sides of the oven and by degrees extending to the centre of the mass of coal. The heat of the fire passing through the sides of the oven enters a first portion of coal in contact with those sides, decomposing it, liberating the bitumen, softening it, and binding the particles together in the form of coke. A second heat again traversing this first portion now become coke, passes into the next portion, forming a second portion of coke. A third heat, passing through these two portions of coke, forms in like manner a third; and so on to the central portions of the mass. But the action of each heat thus exhausted in decomposing a single portion of coal, remains latent for the following portion, so that the coal always remains intact behind the portion in decomposition.

By experiments with our large oven, we have obtained the clearest confirmation of what we have just said. Four hours after a compartment had been heated, we opened the cast-iron door. The coal occupying the centre of the compartment assumed the same form as when it was inserted in the oven, and was even cold, The great heat which had passed through the sides of the compartment had exhausted its action in forming a cake of coke about 3.9 in. thick, which adhered to the sides and the interior surfaces of which were very smooth and glossy, and parallel to those of the compartment. At the inner surface of the coke the action of the heat was arrested, coal being a bad conductor. Some experiments two hours later, that is, six hours after the heating of the oven, gave similar results, with

greater or less thicknesess of coke (according to the duration of the action of the heat), which adhered to the sides. It may be remarked that the thicknesses of the coke formed were not proportional to the duration of the heat applied; they were relatively less for a more prolonged heat. The reason of this is, that the portions of coke which have been formed, not being good conductors of heat, oppose more and more the rapid penetration of the heat. Thus the last portions of coke are longer in formation; and as each face of the compartment contributes its contingent of heat, a space is formed parallel to those faces and in the centre of the cake of coke formed. In this central space the particles of coal of which the new portion of coke is to be formed are conveyed to the last formed portion by the aid of the liquid bitumen, which acts as a vehicle. The space in which the bitumen is to circulate should, therefore, be restricted in the case of coal containing but little bitumen.

Having to deal with different kinds of coal—*meagre* and bituminous coal and coal slow to bake—it was important to be acquainted with these particulars, in order to determine the exact dimensions to give to the compartments to complete the process in a little less than 24 hours, and to ascertain with respect to each kind or mixture of coal the most suitable method of preparing it with a view to its more easy conversion into coke.

The appearance of coal forms but a very slight indication of its nature, or of the manner in which it should be treated in the oven. For this purpose, it is necessary to submit it to a preliminary trial in a crucible.

Incineration will show whether the coal is to be washed. If the coal is already more or less *meagre*, it would, under any circumstances, be advantageous to crush it (if it is not small), and wash it. We have observed, in fact, that coal may become *meagre*, that is, not forming a consistent mass in the coke oven, from excess of earthy matters. This earthy element is often almost completely distinct from the other elements in small coal, and in this case it may be removed by washing. But when the earthy element constitutes an essential part of the coal, it cannot be eliminated.

A trial with the crucible (conducted in a manner to approach as nearly as possible the usual process) shows whether the coal is rich in carbon, hydrogen, or oxygen, whether it will form a consistent mass easily or not, and whether it is bituminous or more or less *meagre* by reason of an excess of carbon or oxygen. The appearance of the coke produced will be a sufficient indication on these points, and will also serve as a guide to the method of treatment to be employed. By a measurement (before and after the operation) of the empty space remaining above the coal in the crucible, we discover whether the mass diminishes or increases in size by coking; and in this latter case, what mechanical preparation the coal should be submitted to.

Supposing that the coal is not too earthy (that is, that it does not contain more than about 2 to 8 per cent. of earthy matter), when the yield in coke with the crucible is between 78 and 83 per cent., it is *demi-meagre* by excess of carbon, and may generally be treated *alone* on a large scale.

If the yield is from 84 to 87 per cent., the coke is generally not very adherent, and coke-dust may be easily rubbed off with the finger. This is anthracite coal, which can only be treated on a large scale by the addition of a small quantity of more bituminous coal, and by properly pounding and mixing the two together.

If the yield of coke is from 88 to 93 per cent., then we have real anthracite, which will not agglomerate at all, and which remains in the crucible after being operated on in the same condition as when placed in it. To transform this coal, so rich in carbon, into coke, it is necessary to mix it with a stronger proportion of bituminous coal than in the preceding case. These two kinds of coal should be well prepared by crushing, and the bituminous coal should constitute at least one-fourth of the weight of the whole mixture, the exact quantity being determined by the exact character of the anthracite.

The smaller the bituminous coal is crushed, when it is to be employed with anthracite, the smaller will be the quantity required to bind the particles of anthracite together.

If, therefore, we wish to economize the bituminous coal, the two kinds should be crushed separately before being mixed together. To obtain a really useful coke, the bituminous element should constitute

one-third of the weight of the whole mixture. If the coal is *meagre* by reason of excess of oxygen, a very small yield of coke is obtained. A yield of 60 per cent. is almost the limit for this kind of coal, which will, however, agglomerate in coke-making on a large scale. But if the yield is less than 60 per cent., it does not agglomerate, or only in a slight degree, like anthracite coal and anthracite, which are too rich in carbon. This oxygenous coal resembles lignite, which also does not agglomerate, and which gives more than half its weight in volatile matter, oxygen forming the greater part.

The water which is introduced with the coal into the compartments of our oven does not generally injure its action nor the quality of the coke, unless an excessive quantity is used. A proportion of 4 to 5 per cent. of water produces, in fact, a more active combustion of the gases in the empty spaces of the oven. But certain kinds of coal, and especially *demi-meagre*, which is so from excess of oxygen, do not agglomerate so well if introduced very small and mixed with more than 5 per cent. of water. Coal which is rich in carbon does not generally present this inconvenience. But some kinds of this coal augment in quantity in coking, and with them a prudent preparation is necessary, in order to avoid difficulty in getting the coke out, and the derangement of the sides of the compartment. The following is the precaution we have taken:

Let us take a block of coal a cubic decimètre in dimensions (decimètre = 3.9 ins.) If we break it into little pieces it could no longer be place in a measure of the capacity of a cubic decimetre. It will be alike impossible if we reduce these pieces to small dust, by reason of the multitude of very small spaces between the particles. But if we add to this fine dust from 6 to 8 per cent. of water, by weight, it will occupy a considerably greater space. It may indeed (according to the fineness of the dust) occupy a space three times as great as the original block of coal.

It may be conceived, therefore, that coal thus increased in bulk previously, and introduced into the compartment, will contract rather than swell during its conversion into coke.

In an oven which would not be so high as ours, this fine coal-dust, swollen with the admixture of water, produces a porous and light coke. It is not so with our oven, because of its high temperature, and the great relative height of the mass upon which we operate, the principal causes of the density of coke. We have not found a great difference of density between coke taken from the base of the mass and that lying immediately next the extreme upper part. We have made numerous experiments on the density of coke produced from the same coal in ordinary low ovens and in our own oven, and we find that ours gives the densest coke.

We ascertain the density of coke (with respect to its apparent bulk) by means of the following formula:

$$d = \frac{p}{P - E},$$

which may serve for any kind of porous body not soluble in water. In this formula, d represents the density of the piece of coke, with respect to its apparent bulk; p is the weight of the coke weighed dry in the atmosphere; P indicates its weight after being made to boil for about ten minutes in water, and then cooled in cold water for twenty or thirty minutes, according to its size; E is its weight in water taken with the areometer, that is, the weight of the body less the weight of a volume of water equal to the bulk of its *real matter*. This formula remains true even when the boiling water might not penetrate into all the little pores of the coke. In this case the formula

$$D = \frac{p}{p - E}$$

would give the real density, D, of the matter of the coke, without regard to its exterior bulk.

A PROSPECTUS has been issued of the Franco-Egyptian Telegraph Company (Limited), with a capital of £410,000, in shares of £10, to eastablish "a direct line between England, France, Algeria, and Egypt, hereafter to be extended to India and China, as may be determined by the shareholders." It is to proceed through France to Marseilles, *via* the submarine line from Dover to Calais, and thence by cable to Algeria and Egypt, and is simply a competitive undertaking against the Falmouth, Gibraltar, and Malta, and the Anglo-Mediterranean companies.

HYDRAULIC RIVETING MACHINE.

Translated from "Annales du Génie Civil."

The important operation of riveting the plates of boilers has hitherto been done almost exclusively by hand. Machines have, indeed, been invented for that purpose, but are complicated and costly, and but imperfectly accomplish the end in view. All are constructed upon the same principle, and differ only in some specialty of motion, or in the means employed to move the riveting lever. A cast-iron anvil receives the point of the rivet, which is applied red-hot, and then pressed with great force. A second lever is sometimes used to force the plates together before the riveting lever is applied. Without this contrivance the plates are forced apart rather than together by the process of riveting.

When riveting is done in the ordinary way, not only is the part of the rivet projecting beyond the plate compressed, but that within the hole is also spread. This acts upon the plates, and tends to separate them, as illustrated in Fig. 1. If the

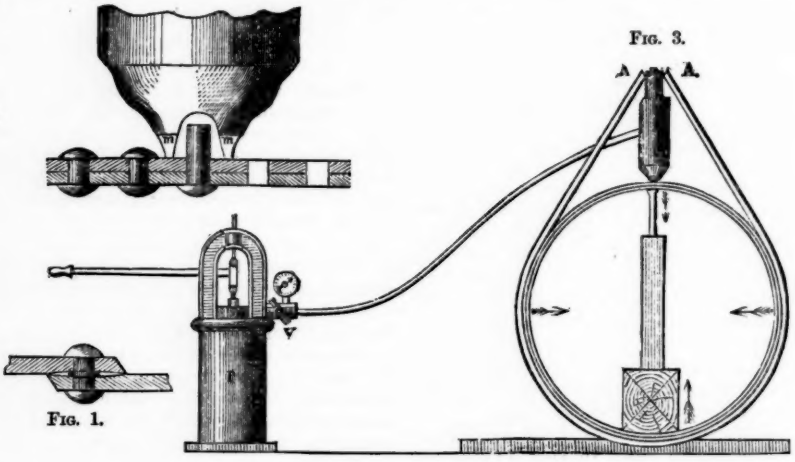


FIG. 1.

FIG. 3.

second lever is used this difficulty is obviated, as the riveting becomes almost perfect in all respects, and much better than that done by hand. But, though the work of these machines is good, it is attended with many hindrances and inconveniences.

The height of the anvil ought not to be considerable, if sufficient resistance is to be opposed to the lever. The boiler must often be riveted in sections, ring by ring. It often happens that, in the manufacture of boilers 9 to 12 metres in length, of 7 to 10 rings, it is necessary to interrupt operations as many times, in order to push the boiler forward or back. Every one knows the disadvantages of such suspension of work.

Again, these machines can do riveting only upon cylindrical portions of the boiler; in other parts the work must be done by hand.

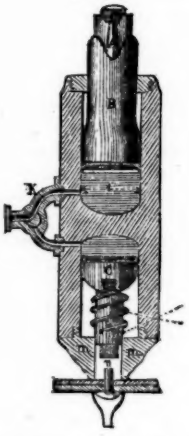
The conditions of a good riveting machine are the following: It should exercise a pressure as great as possible upon the plates without separating them, and while this pressure is acting, a stamp should be brought to bear upon the projecting bolt, so as to form the head of the rivet. Besides, the machine should be so light that two workmen can carry it and fit it to any part of the boiler where the equilibrium will not be disturbed by the additional weight.

It is evident that the machines heretofore employed do not satisfy these conditions. Fallenstein has solved this problem in a rivet machine which employs the hydraulic press.

The boiler is set as if the work were

to be done by hand. Fig. 2 represents a rivet machine (scale $\frac{1}{8}$) and Fig. 3

FIG. 2.



shows its application to the boiler. A fork A A serves to hold a strong chain which surrounds the boiler. This chain should be somewhat slack, so that the machine may be fitted to any part of the boiler, and it should move back 52 millim. after having finished each rivet.

The machine should be placed so that its axis coincides with that of the rivet hole. The bolt is put in red-hot; the small hydraulic pump P is then put in action. By the contrivance shown in Fig. 2 water is admitted by the valve K into the upper compartment, lifting the piston B. This tightens the chain, bringing *m m* against the plates, and forcing them together. The pressure must be determined by the thickness of the plates. Two strokes of the piston are sufficient. The stopcock K is now turned so as to keep the piston B under pressure, while the lower space is put into communication with the hydraulic press. The consequence is that the piston C is forced down, and the rivet is headed.

In order to vary the amount of pressure, the valve V is opened, so that the water can leave the pump; the pressure then ceases, and the piston C is raised by the recoil, thus gaining time, as otherwise a lever (indicated by the dotted line in Fig. 2) would be necessary.

The stopcock K is now set to its first position, the water which fills the upper space escapes, the piston descends of its own weight, and the chain slacks, so that the machine may be moved to the next hole.

HOW RAILS ARE MADE IN FRANCE.

From "The Iron Age."

PUDDLING PROCESS.

The hearth is cleaned out and made up once in every 24 hours; fragments of scrap-iron and ends of sheet-iron, bars, etc., are laid on the middle of the hearth and heated until the scrap and the silica left from the previous day are partly melted together. When there is one or two inches of molten matter, water is thrown over to solidify it, and a layer is formed which protects the iron-plate, and increases the yield.

440 lbs. of white pig iron, previously heated, is charged at a time; the grate is cleaned, and 8 inches of coal are charged; the slag of the preceding heat is drawn off; a very little cinder is added, and several handfuls of mill cinder. The door is accurately closed and full heat is given for 30 or 40 minutes. During this time the grate is charged five or six times. Hot pig is known by its fluidity, whilst cold or slightly carburetted pig is known by the specks and skins on its surface. The bath is then stirred; with good qualities of pig, 5 or 6 hooked bars can be used at the same time. With hard iron only 2 or 3 can be used at once, as the bath is very dry. During this operation the grate is charged rapidly twice, so as to admit no air. At the end of 10 or 15 minutes the hearth is covered with agglommerated and very dry lumps. The damper is then closed for 6 or 7 minutes, and without disturbing the fire, the balls are made so as to inclose the particles of iron immediately upon their coming to nature. Particular care is taken to leave no isolated fragments on the hearth, as they would be turned to completely fibrous iron; for the same reason the first balls taken out are more in grains, and the

last ones more fibrous. After 5 or 6 minutes of arduous labor the damper is opened and the furnace is fired up strongly for 1 or 2 minutes. The balls are then ready, and are taken at once to the hammer and the rolls.

20 charges are made in 24 hours. The waste is 12.5 per cent.; the consumption of coal is 10.5 hectolitres per ton of iron. 40 lbs. of scrap is added to increase the yield. Iron filings sometimes thrown in, make strong but dry iron. A premium of 20 cents is placed on every 200 pounds in excess, and a fine of 20 cents on every 200 pounds of deficit, on the basis of 1,143 pounds allowed to produce 1,000. A premium of 2 cents is also given for every hectolitre of coal economized below 10 hectolitres per ton.

The finished bars from each furnace are piled and classified: 1, *fibrous;* 2, *metis;* 3, *grained.* The cut pieces are stored away in compartments corresponding to each furnace, with the fracture turned outward to allow of ready inspection. As the men are paid according to the two classes of iron produced, the *inspecteur du puddleage"* makes a note of the quantities of the first and second class iron produced per furnace. This method produces a certain degree of competition among the men, and requires a strict control of the classification.

One steam hammer of 3,300 lbs. is erected for every 10 puddling furnaces, and requires steam at 2½ atmospheres for 10 horse-power. At the new mill a steam hammer of 66,000 lbs. does the work of 6 furnaces, and as each furnace yields 50 balls in 12 hours, 300 balls have to be shingled during this time. One ball takes on an average 45 seconds, so that the 300 balls require 3 hours 45 minutes.

MANUFACTURE OF RAILS.

The quality of pig adopted for rails is No. 6; numbers 1 to 6 represent charcoal iron and merchant bar. The color of each quality is indicated by a letter: A represents gray iron, and H the hardest white. The best quality for rails is termed F, which is white, lamellar, compact, and brilliant, as distinguished from G and H, which are cavernous, and E, which presents a less brilliant, non-radiating, lamellar structure. The quality D is mottled at the centre; C is mottled throughout, and A and B are completely gray. The best pig for rails presents no openings along the edges, and a short, neat fracture. The grains are pretty large and brilliant without. We will describe the composition of the rails of the Paris and Lyons Railroad.

The *piles* for *top and bottom slabs* are 4 ft. long, 7.88 ins. wide and 7 ins. high, made up of 10 layers. The weight is about 385 lbs. Each layer is made of 3 bars with joints crossed; the top and bottom layers are also of 3 bars, the middle one 4 ins. wide, is of grained iron; the remainder is metis iron generally.

The *rail piles* consist of top and bottom slabs, with 7 intermediate plates, 3 of which are ends of rails rerolled. The weight of the top and bottom slabs together is one-third of the total weight of the pile. The contiguous plates are of fine-grained iron to produce a good weld. The remaining layers are of puddled bars and rerolled iron.

The piles for top and bottom slabs are placed 4 together in a reheating furnace; 14 charges are made in 24 hours. The piles are then passed 4 times through the roughing rolls, beginning with the plates edgeways and turning them over 90 deg. at each successive pass. Four passages flat are then made at the finishing rolls. The waste in the furnace is 5 per cent.; 1 fireman and 2 assistants attend to the reheating furnace. The consumption of coal is 5.5 hectolitres per ton of slabs. The slabs are cut to two different lengths, so that the weight of the rail pile can be kept pretty uniform by using a longer or shorter slab.

The rail piles are placed on the hearth of the reheating furnace at points on either side of the doors. They are heated for three-quarters of an hour without change of position, and are then turned over once, beginning at the bridge. After 10 minutes the pile next to the bridge is turned over again and taken to the rolls. The second pile is turned a second time to prevent burning, and the remaining ones are turned over consecutively. To keep the sides of the piles always at the same temperature, the fire is quickened at first at one end of the grate and toward the end at the other end of the grate, so as to change the temperature of the two walls of the furnace. Between each heat, the hearth is levelled down so as to allow

no channels under the piles where the gases would circulate and burn them. The hearth is usually made up of silicious pebbles pulverized. When the piles are taken out they are at a white heat at both ends, but less bright in the middle.

The waste in reheating and rolling the rail piles is 4 per cent., to which must be added a loss, owing to the average rejection of 6 per cent. of the finished rails for flaws, and a loss of 1.06 per cent. from the crop ends; 18 charges are made in 24 hours; 878 lbs. of coal are consumed per furnace in 12 hours. Each furnace is worked by one fireman and one assistant; a second assistant attends to two furnaces at once.

ROLLING OF RAILS.

The roughing rolls are three high. This is essential, as if the plates are not welded at the third groove they will not weld subsequently, being too cold; the passages must then be sufficiently rapid to maintain a welding heat at the third groove. In all, 6 passages are made through the roughing, and 4 through the finishing rolls. In the latter rolls the third and fourth grooves are repeated twice, as they wear out the most rapidly, and the cylinpers could not last the ordinary length of time, *i. e.*, a week without being turned.

In a rail of the following dimensions, height, 5.27 ins.; head, 2.40 ins.; neck, 0.63 ins., the grooves are as follows:

1st groove ....neck, 2.71 ins.....head, 4.40 ins.
2d groove ....neck, 1.16 ins.....head, 3.40 ins.
3d groove ....neck, 0.67 ins.....head, 2.61 ins.
4th groove....neck, 0.51 ins.....head, 2.36 ins.

The axis of each groove is horizontal, and passes through the middle of the neck, but not of the head, for the first and second grooves, so as to force the iron into the grooves of the "cylindre femelle," Once a week the cylinders are "refreshed" in a lathe, and the grooves turned down to the original sections. The rolls then have only to be brought nearer together. The vertical wear is thus neutralized, but the lateral wear shows itself, especially in the third, or before the last groove. To remedy this, the third groove is made 0.12 inches smaller horizontally than the fourth or finishing groove. The head is rolled flat, until the last groove, when a certain convexity is given; a strong pressure (0.51 in.) is given at the neck so as to force the iron rapidly into the convex space.

From the dimensions above given, for neck and head of last groove, which represents the section of the rail at a dark red heat, and from those of the rail when cold, 0.63 and 2.40, it will be seen that during the cooling the neck and head both expand somewhat, whilst the length only decreases.

The rolls made 60 revolutions per minute for double-headed rails, and 75 for the American form. Their diameters are 19.29, 19.68, and 21.65 ins. The diameter of the upper cylinder is 0.23 in. in excess of the lower one, so that the rail will tend to wind around it and is easier to take hold of when it comes through. A play of 0.078 in. is left between the cylinders.

In the roughening train the differences are still greater. The diameters of the outside rolls differ by 0.67 in., and the middle cylinder has a diameter medium between the two. In the finishing train the male cylinder is chilled, and the female cylinder is cast in sand, so as not to wear out the bearings too rapidly.

FINISHING.

The rails are at once sawed at both ends to the required length, and the rough edges filed down whilst still hot.

When cold they are taken to a shed, straightened, planed and punched. The presses are of two kinds: horizontal, worked by three men; and vertical, worked by two men. A particular machine is also adapted for this purpose, which works with more exactness. The ends are then planed to the right length.

The rails of the Creusot are known for their hardness and perfect weld; their faults are brittleness and unequal lengths. Cinder containing phosphorus has such a marked influence on the brittleness of iron, that one-twelfth or one-thirteenth more phosphorus than usual in the cinder bath was found to make brittle and steely rails.

An English inventor named Jackson has devised a breakwater, consisting of a number of cast-iron tubes fastened together so as to form a sort of honeycomb, which is so placed that the axes of the pipes are parallel with the direction of the most dangerous winds or currents, the waves flowing through the pipe.

EXPLOSIVE AGENTS.*

From "The Journal of the Chemical Society."

The degree of rapidity with which an explosive substance undergoes metamorphosis, as also the nature and results of that metamorphosis, are, in the greater number of instances, susceptible of several modifications by variations of the circumstances under which the conditions essential to chemical change are fulfilled. Gun-cotton furnishes an excellent illustration of the manner in which such modifications may be brought about. If a loose tuft or large mass of gun-cotton wool be inflamed in open air by contact with, or proximity to, some source of heat, the temperature of which is about 135 degs. C. or upwards, it flashes into flame with a rapidity which appears almost instantaneous, the change being attended by a dull explosion, and resulting in the formation of vapors and gaseous products, of which nitrogen-oxides form important constituents. If the gun-cotton be in the form of yarn, thread, woven fabric or paper, the rapidity of its inflammation in open air is reduced in proportion to the compactness of structure or arrangement of the twisted, woven, or pulped material; and if it be converted by pressure into compact masses, solid throughout, the rate of its combustion will be still further reduced. If to a limited surface of gun-cotton, when in the form of a fine thread or of a compactly pressed mass, a source of heat is applied, the temperature of which is sufficiently high to establish the metamorphosis of the substance, but not adequate to inflame the products of that change (carbonic oxide, hydrogen, etc.), the rate of burning is so greatly reduced that the gun-cotton may be said to smoulder without flame; the reason being that the products of change, which consist of gases and vapors, continue, as they escape into air, to abstract the heat developed by the burning gun-cotton so rapidly that it cannot accumulate to an extent sufficient to develop the usual combustion, with flame, of the material.

If, on the contrary, the escape of the gases from burning gun-cotton be retarded, as by enclosing it in an envelope or bag of paper, or in a vessel of which the opening is loosely closed, the escape of heat is impeded until the gases developed can exert sufficient pressure to pass away freely by bursting open the envelope or aperture, and the result of the more or less brief confinement of the gases is a more rapid or violent explosion, and consequently more perfect metamorphosis of the gun-cotton. So, within obvious limits, the explosion of gun-cotton by the application of flame or any highly heated body is more perfect in proportion to the amount of resistance offered in the first instance to the escape of the gases; in other words, in proportion as the strength of the receptacle enclosing the gun-cotton, and the consequent initial pressure developed by the explosion, is increased. Hence, while gun-cotton has been found too rapid or violent in its explosive action when confined in guns, and has proved a most formidable agent of destruction if enclosed in metal shells or other strong receptacles, it has hitherto been found comparatively harmless as an explosive agent if inflamed in open air or only confined in weak receptacles.

Other explosive compounds, and also explosive mixtures, are similarly influenced, though generally not in such various ways, by the circumstances attending their metamorphosis. Thus the rapidity of the explosion of gunpowder is modified by variations in its density and state of division, and in the degree of facility afforded for the escape of the generated gases, and consequently of the heat which is disengaged during the explosion. A charge of gunpowder in an open canister, will explode with more violence if ignited at the bottom than if the spark be applied at the top. The body or mass of the powder in the former case evidently serves to exert a pressure, which is always essential to a violent explosion.

The product of the action of nitric acid upon glycerin, which is known as nitro-glycerin or glonoin, appears to be susceptible of only two varieties of decomposition. If a sufficient source of heat be applied to some portion of a mass of this liquid in open air, it will inflame and burn

* An abstract of a paper by F. A. Abel, F.R.S. The original essay by the same Author, is to be found in "Philosophical Transactions" for 1869.

gradually without any explosive effect; and even when nitro-glycerin is confined, the development of its explosive force by the simple application of flame or of other sources of heat, by the ordinary modes of operation, is difficult and very uncertain. But if the substance be submitted to a sudden concussion, such as is produced by a smart though not very violent blow from a hammer upon some rigid surface on which the nitro-glycerin rests, the latter explodes with a sharp detonation, just as is the case with gun-cotton. Only that portion of the explosive agent detonates which is immediately between the two surfaces brought into sudden collision; the confinement of this portion between the hammer and the support, combined with the instantaneous decomposition of the portions struck, prevent any surrounding freely exposed portions from being similarly exploded by the detonation. A similar result is obtained if *any* explosive compound or mixture be submitted to a sufficiently sharp and violent blow, but the tendency of surrounding particles to become inflamed by the detonation is in direct proportion to the rapidity of explosive action of the substances.

The practical difficulties and uncertainty which attend attempts to develop the explosive force of nitro-glycerin by the agency of flame or the simple application of any highly heated body, even when the material is confined in strong receptacles (such as iron shells or firmly tamped blast-holes), appeared fatal to any useful application of the powerful explosive properties of this substance, until M. Alfred Nobel's persevering labors to utilize nitro-glycerin, eventually resulted in the discovery of a method by which the explosive power of the liquid could be developed with tolerable certainty. M. Nobel first employed gunpowder as a vehicle for the application of nitro-glycerin. By impregnating the grains of gunpowder with that liquid, he added considerably to the destructive force of the powder when exploded in the usual way, in closed receptacles. M. Nobel's subsequent endeavors to apply nitro-glycerin *per se* were based upon the belief that its explosion might be effected by raising some portion of a quantity of the liquid to the temperature necessary for its violent decomposition, whereupon an initiative explosion would be produced which would determine the explosion of any quantity of the substance.

I have never suceeded in effecting the *explosion* of nitro-glycerin by simply bringing it into contact with an inflamed or incandescent body, but the following results illustrate the manner in which a score of heat may operate in accomplishing the explosion of this substance.

A piece of very thin platinum-wire, stretched across between the terminals of two insulated copper wires, was immersed in nitro-glycerin. These wires were connected with a Bunsen battery of five large cells, and a second piece of platinum-wire, similar to that immersed in the liquid, was introduced into the circuit. This was then completed, with the intervention of a long piece of platinum-wire between one of the conducting-wires and the battery. The resistance presented by this interposed platinum-wire was gradually reduced by shortening it, until ultimately the short platinum-wire not immersed in the nitro-glycerin was fused. The latter was not exploded nor inflamed, nor was the wire enclosed in it fused, the heat developed in the latter being rapidly absorbed by the surrounding liquid and removed by convection. A very much thicker platinum-wire was now substituted for the thin one, and immersed in the liquid; a second short piece was not interposed in the circuit in this instance, but a long platinum-wire, of the same thickness as the above, was employed, as a means of gradually reducing the resistance in circuit. When the length of this wire had been reduced to five inches, it was raised to bright redness; this state of things was maintained for about one minute, but the short wire in the nitro-glycerin did not glow at the expiration of that period, nor did the liquid exhibit any signs of change, but the glass vessel containing it had become very warm. The long platinum-wire was then removed, and the full battery power was passed into the short wire immersed in the liquid. After the lapse of about one minute the latter began to assume a brownish color (like that of a solution of iron), which rapidly deepened, though no red vapors were perceptible in the upper portion of the vessel, until after the lapse of 90 seconds, when the nitro-glycerin exploded with great violence. Several unsuccessful attempts were afterwards made to explode nitro-glycerin by

means of the electric spark, but eventually, by allowing the sparks from a Ruhmkorff coil with a Leyden jar attached to pass uninterruptedly between the poles, which were just touching the liquid, the latter being splashed up by the discharges, the surface of the liquid speedily darkened, and in 30 seconds it exploded.

It is evident from these results that nitro-glycerin can be *exploded* by electric agency, or by direct application of any other source of heat only, if the intensity of the latter, or the period during which it is applied, suffices to develop decomposition in some portion of the liquid; when once this is established, the temperature is soon raised by accumulation of heat (especially if the application of external heat be continued) until it attains the point at which explosion occurs.

M. Nobel has described various devices for effecting this so-called *initiative* explosion of some portion of a nitro-glycerin charge, of which evidently the most successful are the explosion of a small confined charge of gunpowder, or of a large percussion-cap, when immersed in or placed immediately over the nitro-glycerin. M. Nobel, however, classes these two modes of ignition in which an explosion or detonation is applied as the exploding agency, together with various others in which the simple application of a high temperature to some portions of the nitro-glycerin is proposed as the means of explosion; and although, in his published description of these various methods, he refers to difficulties in developing explosion by those which relate to the simple application of flame or other heated body to the nitro-glycerin, yet he refers the effect produced by the confined charge or the percussion-cap only to the heat developed by the ignition of these exploding agents.

The circumstance that nitro-glycerin, or any preparation of that substance, may be violently exploded *when freely exposed to air*, by the explosion in contact with it of a small confined charge of gunpowder, or of a detonating substance, while other modes of explosion by the application of heat or flame, which have been described by M. Nobel, only develop explosion under special conditions, points to a decided difference between the action of the two modes of ignition, and appears to indicate that it is not simply the heat developed by the chemical change of the gunpowder or detonating powder which determines the explosion of the nitro-glycerin.

An experimental investigation of this subject has left no doubt on my mind that the explosion of nitro-glycerin through the agency of a small detonation is due, at any rate in part, to the mechanical effect of that detonation, and that this effect may operate in exploding the nitroglycerin quite independently of any direct action of the heat disengaged by the gunpowder or other detonating charge.

I was led to examine into this question by an interesting and important observation recently made by my assistant, Mr. E. O. Brown, in connection with gun-cotton. The fact that the violent explosion of this substance cannot be developed except when it is confined in receptacles of some strength, has been up to the present time accepted as indisputable. It occurred, however, to Mr. Brown that as gun-cotton is analogous in its nature and operation as an explosive agent to nitro-glycerin, differing principally from that substance in the rapidity and consequent violence of its explosion, it might also, like nitro-glycerin, be susceptible of violent explosion when unconfined, by being ignited through the agency of detonation. This proved to be the case; for upon exploding a small charge of detonating powder in contact with, or in the immediate vicinity to, compressed gun-cotton freely exposed to air, instead of the latter being simply inflamed and then burning gradually, as would be the case if it were brought into contact with flame or any sufficient source of heat, it explodes with great violence, exerting a destructive action equal to that of nitro-glycerin, and decidedly greater than that produced by gun-cotton when exploded under the conditions hitherto believed to be those most favorable to the full development of its explosive force. The explosion of a small mass of compressed gun-cotton in this manner suffices to determine the similarly violent and apparently simultaneous explosion of small detached masses of the same material, which may indeed be placed at distances of 0.5 to 1 in. from the original source of the explosion or from each other. Thus, rows of detached masses of gun-cotton, placed on the

ground, and extending 4 or 5 ft., have been exploded with most destructive results, by the firing of a small detonating tube in contact with the piece of compressed gun-cotton which formed one extremity of the row or train, the explosion of the entire quantity being apparently instantaneous and equally violent throughout.

In the first experiments instituted with the view of ascertaining the conditions to be fulfilled for insuring the development of the violent action, or for accomplishing the detonation of gun-cotton when perfectly unconfined, the following points were observed :

1. If a confined charge of mercuric fulminate be placed in contact with, or buried in gun-cotton which is in the form of wool or spun-yarn, its explosion does not develop the violent action of the gun-cotton, as would be the case if the latter were in the form of a compact, hard, and homogeneous mass (as obtained by submitting finely divided gun-cotton to powerful pressure). The light and loose gun-cotton is simply scattered with violence ; portions of it are sometimes ignited by the flame of the exploding fulminate, the latter result being obtained with greater certainty the less violent the detonation produced by the fulminate charge.

2. The detonation of a small mass of compressed gun-cotton, freely exposed to air, by means of a mercuric fulminate charge, does not accomplish the explosion of light gun-cotton wool or yarn placed in immediate contact with it ; the latter is scattered and partially inflamed, as in the preceding case.

3. If the detonation of the fulminate charge which is placed in contact with a mass of compressed gun-cotton is not sufficiently violent or sharp to effect the explosion, the solid mass is shattered and violently dispersed ; if the detonation is upon the verge of that required for determining the violent explosion of the gun-cotton, no inflammation of the latter takes place ; but if the explosion of the fulminate charge is comparatively feeble, portions of the gun-cotton are inflamed at the moment of dispersion of the mass.

4. Explosive substances which are inferior to mercuric fulminate in the suddenness and consequent momentary violence of their detonation, cannot be relied upon to effect the violent explosion of freely exposed gun-cotton, even if employed in comparatively considerable quantities. Thus, even ordinary percussion-cap composition, which consists of a mixture of mercuric fulminate and potassic chlorate, cannot be used for the detonation of freely exposed gun-cotton, unless a much more considerable amount be used than is necessary of pure mercuric fulminate for that purpose. Many other detonating mixtures, exploding less rapidly and violently than the above, have been tried without success in very considerable quantities, as agents for developing the detonation of gun-cotton in open air.

5. The quantity of confined mercuric fulminate required to effect the detonation of freely exposed gun-cotton, is regulated by the degree to which the sharpness of its explosion is increased by the extent of accumulation of force, consequent upon the strength of envelope in which the fulminate is confined. From 1.3 to 2.0 grms. (20 to 30 grains) are required to detonate the gun-cotton, if the fulminate be confined in a thin case of wood, or in several wrappings of paper, while the same result can be produced with 0.32 grm. (5 grains) if that amount be confined in a cap of thin sheet metal.

If the fulminate be placed in a wide paper cylinder open at the top, which is rested upon the gun-cotton surface, or if it be placed in a heap directly upon the surface of gun-cotton, and if in either instance the violent explosion of the fulminate be effected through the agency of a platinum-wire placed at the *base* of the heap, about 2 grms. (25 to 30 grains) of fulminate will also accomplish the detonation of the gun-cotton, the violent action of the fulminate being, in these instances, developed by the confinement of the portions first ignited in a weak envelope, which consists partly or entirely of the surrounding or superincumbent fulminate.

6. It need perhaps scarcely be stated that the degree of proximity of the detonating charge to the gun-cotton, which is essential for the explosion of the latter, is regulated by the violence of the detonation produced. 0.32 grm. (5 grains) of fulminate inclosed in a metal cap must be placed in a close contact with (*i. e.*, closely surrounded by) the unconfined gun-cotton, in order to effect its explosion, while 1.3 grm. (20 grains), similarly confined, will

produce the same result if placed at least 0.5 inch distant from the surface of the compressed gun-cotton.

The foregoing facts appear to point to the mechanical action of a detonation as as being the real cause of the violent explosion of freely exposed gun-cotton or nitro-glycerin. At any rate they appear to indicate decisively that such explosion is not a result of the direct application of the heat developed by the explosion of the detonating materials. If it were so, then the detonating mixture described as percussion-cap composition, and other explosive mixtures, the ignition of which is attended by much greater development of heat than is obtained by the ignition of pure mercuric fulminate, should explode freely exposed gun-cotton more readily than the latter does; the readiness with which the gun-cotton is exploded should be solely proportionate to the amount of fulminate employed; and gun-cotton should be more readily exploded in the loose and open condition than in the compact and highly compressed form; for the latter presents it in the condition least favorable, and the former that most favorable to ready and rapid ignition by heat. Again, the actual temperature required for the explosion of nitro-glycerin is very considerably higher than the exploding temperature of gun-cotton; the former may be heated to a temperature of 193 deg. C. (380 deg. F.) for some time without exploding, while the latter inflames at a temperature of 150 deg. C., yet a much smaller charge (not more than 0.2 of the amount) of fulminate suffices for the explosion of unconfined nitro-glycerin than is needed for the detonation of gun-cotton. On the other hand, a quantity of confined percussion-cap composition which, if it were pure mercuric fulminate, would be altogether inadequate for the detonation of gun-cotton, suffices for the detonation of nitro-glycerin.

Although the foregoing facts appear to afford indisputable evidence that the direct application of heat, from an exploding charge of detonating powder, is not concerned in developing the violent action of gun-cotton or nitro-glycerin, an attempt has been made to devise some experiments in which the detonation of either of those substances by the agency described should be accomplished in such a manner as to interpose an effectual barrier between the material to be exploded and the heated gases or flame resulting from the ignition of the charge of fulminate destined to furnish the initiative detonation.

Some small pellets of compressed gun-cotton saturated with nitro-glycerin were placed in a cylindrical wooden case open at one end and fixed at the bottom of a trough of water; the air-spaces between the separate pellets were thus occupied by water, the height of which above the charge was about one foot. An electric fuse, primed with 2.6 grms. (40 grains) of mercuric fulminate was weighted and placed at the bottom of the trough, on one side of the cylinder, and at a distance of 2 in. from it. The detonation of the fulminate did not explode the charge; the experiment was then repeated, the water-space which intervened between the fuse and the wooden cylinder being reduced to 1 in. In this instance the firing of the fuse exploded the immersed pellets, the water was projected to a great height, the trough was broken into small fragments, and a crater was formed in the ground upon which it rested. This experiment was repeated with the same results. A small cylinder of compressed gun-cotton saturated with nitro-glycerin, was inclosed in a paper case, which was thickly coated with a gutta-percha and pitch cement. A screen of thin sheet copper was placed at the bottom of a trough, and the waterproofed charge of explosive material was weighted and placed upon one side of the screen at 0.25 in. distance from it. A waterproofed electric fuse primed with 2.6 grms. (40 grains) of mercuric fulminate was placed on the other side of the screen at a distance of 1 in. from the latter; the trough was then filled with water, so that the screen, charge, and fuse were each surrounded and separated by the liquid. In the first experiment, the explosion of the fuse did not affect the charge, but upon repeating the experiment with a fuse placed at a distance of 0.75 in. from the screen, the charge was violently exploded, as in the former experiment.

A precisely similar experiment was tried with cylinders consisting of compressed gun-cotton only, and enveloped in coatings of some thickness of the gutta-percha cement; but even when the charge and the fuse were placed close to the sides of the screen which separated them under

water, the gun-cotton was not exploded by the detonation of the fulminate; the same negative result was obtained when a fuse (enveloped in the waterproof coating) was placed immediately upon a gun-cotton charge enclosed in the paper case and waterproof cement, and exploded under water or in open air. These negative results were instructive, as indicating that the thick yielding envelope which enclosed the gun-cotton charge (possibly assisted by the thin air-cushion by which the enclosed charge was also surrounded) served to protect the comparatively less sensitive explosive material, gun-cotton, by reducing or absorbing the power of the blow or concussion (or whatever the disturbing impulse may be). This explanation was shown to be correct by the fact that a cylinder of gun-cotton, enclosed in a water-tight case of thin sheet metal, and immersed in water, was violently exploded by a fulminate-fuse which was placed by its side, with about 0.25 in. of intervening water.

Some nitro-glycerin, contained in a glass beaker, placed at the bottom of the trough filled with water, was not exploded by a fulminate-fuse, placed at a distance of 2 in. from the side of the beaker; but when the intervening water was reduced to little more than 1 in., the detonation of the fuse exploded the nitro-glycerin.

A 12-pounder cast-iron shell was filled about one-half with small granules of gun-cotton impregnated with nitro-glycerin; it was then filled with water, and a waterproof fulminate-fuse was inserted through the plug which closed the shell. The fuse and each separate granule of the explosive agent were therefore surrounded by water. Upon ignition of the fuse, the shell (which was placed in a very strong room) exploded with a violent report, and was broken into very small fragments, the greater number of which were buried in the timber which lined the cell. A similar shell was half filled with the same explosive agent; the spaces between the granules and the empty portion of the shell were then filled with a thin plaster of Paris mixture, and a fulminate-fuse was imbedded in the solid plaster which filled the upper half of the shell. The explosion of the fuse was attended by a precisely similar result to that obtained in the preceding experiment.

It is believed that these experiments, together with the facts regarding the behavior of gun-cotton which have been stated in the earlier part of this paper, afford convincing proof that the violent explosion of gun-cotton and nitro-glycerin through the agency of a detonating fuse, must be ascribed either to the mechanical effect of that detonating (*i. e.*, to the work done upon the particles more immediately exposed to the blow or concussion of the detonation), or to the development of a disturbance of chemical equilibrium in the explosive agent by the suddenness and peculiar character of the concussion, or by the powerful vibrating impulse which the detonation establishes.

Mr. Joseph Woodward has taken out a patent which may turn out to be of great importance to every iron smelting district in England. The millions of tons of slag running from the blast furnaces, and piled up in such unsightly heaps in all such districts, are to be utilized in the manufacture of the new brick. It is stated that the brick is damp-proof, that it is very solid and firm, without flaw, and pleasing to the eye. The inventor opines that it is likely at once to take the place for ornamentation at present occupied by the costly Staffordshire blue brick. Mr. Woodward's brick can, it seems, be produced so economically, that they can be offered at less per thousand than the ordinary clay and fire bricks.

Europe.—Europe contains 70,718 miles of railway, composed of 150,000,000 cwt. of iron rails, on which 400,000 passenger carriages and 600,000 baggage cars are dragged by 18,000 locomotives, over 52,000 bridges and through 34 miles of tunnels, at the rate of $60,000,000 per annum, with a consumption of 4,000,000 tons of coal.

British Pacific Railroad.—Mr. Waddington has arrived at Ottawa, from London, England, to press upon the attention of the Government the construction of the British Pacific Railway. He believes the best point at which to commence is the mouth of the Neepigon River, on Lake Superior. All the money required for the work can be had in London.

SCREW PILES.

From "The Building News."

It is a fact worthy of notice that although screw piles have been in use in England and the Transatlantic continent for nearly forty years, they have scarcely been employed in France on any scale that warrants a description. This is the more difficult to understand since the value of the principle is universally recognized, and in many situations it would be impossible, in an engineering point of view, to obtain a foundation without them. It is, in fact, only since their introduction, and the establishment of their advantages, that certain structures—light-houses, for example—have been successfully erected on shifting sands, and other kinds of foundations, upon which, by the ordinary methods in use, no superstructure could have ever been erected. On the Bombay, Baroda and Central India Railway screw piles were employed as the means of obtaining a foundation in the numerous rivers crossed by that line. They were screwed down, sometimes by capstan power, at others by yoking native cattle to the end of a long lever, until they came to a firm substratum. Several of these, properly braced together, formed the piers upon which the iron girders were placed, which were nearly all of a uniform span of sixty feet. Unquestionably, one of the chief merits of the screw pile is its great suitability for rapid rivers, which sometimes during a severe drought are nearly dry, and which, in flood time, roll down their waters with all the impetuosity of a mountain torrent. The screw pile not merely fastens itself firmly into the ground, but its comparatively small sectional area offers but little impediment to the motion of the stream. At the same time it must not be forgotten that there are certain descriptions of substrata for which the screw pile is not adapted, and where it becomes necessary to seek a foundation by the employment of other means. We shall allude to this presently. The first application of the screw pile principle was made by the inventor, Mr. Alexander Mitchell, in the harbor of his native town, Belfast, where some buoys were successfully anchored in that manner. The light-houses at Fleetwood and the Maplin sands demonstrated a few years afterwards that the invention was likely to prove of great utility to engineers. The former of these was carried away bodily about a month ago by a schooner which ran into it. It was only the superstructure that fell, the piles remaining in their place. A large number of dock walls, jetties, breakwaters and other engineering works have been erected solely upon foundations secured through the agency of these piles. A brief description of their advantages and suitability for the purposes of foundations will prove of interest to not only our professional readers, but to the amateurs as well.

A screw pile only differs from an ordinary one of timber, or cast or wrought iron, by being furnished at the lower extremity with a screw or spiral. The screw is of particular construction, as it is provided with only two or three turns, or more correctly blades, which are of different diameter. The upper of these has the greatest resistance to contend with, and is therefore of a larger diameter than the others, sometimes reaching the dimension of four feet. The pile being adjusted in either a vertical or inclined plane as required, a movement of rotation is imparted to the upper extremity, and the penetration commences. One of the chief merits in thus obtaining a foundation is, that the pile does not dislodge the earth near and round about it, but bores its own way, so to speak, without disturbing the neighboring layers. Thus fixed in position, the pile can be used either as a mooring post, or as a portion of a pier upon which to erect a bridge, jetty, or other analogous superstructure. The screws are either cylindrical or conical, of cast or wrought iron, and the piles may be also of either material, or of timber. The employment of the latter in connection with the screw end is rare. According to the nature and consistency of the ground to be penetrated, so must the shape and size of the screw be proportioned. If the earth be of a loose, friable, easily penetrable character, a cylindrically formed screw will answer for the purpose ; but if it be of a compact, tenacious description it becomes necessary to use a

screw in the shape of a cone. No screw, whatever may be its form and powers of boring, will penetrate into absolute rock, but the principle has been successfully applied in instances where the foundation was a bed of coral. It is manifest that the power required to get the pile down will depend altogether on the nature of the ground to be penetrated. As a rule, a capstan worked by manual labor is found sufficient. One of these machines, with eight bars, about 20 ft. in length, each manned by 5 or 6 laborers, has been found capable of getting down a pile 4 ft. in diameter, to a depth of 15 ft. in an hour and a half, in ground composed of sand, clay, and loose rock of a schistose nature. The conditions being the same, a period of 2 hours was sufficient to sink a screw pile to a depth of 21 ft. In cases where it is not possible to employ the leverage of capstan bars—that is, where room cannot be obtained for erecting a platform—the head of the capstan is furnished with a wheel which can be worked by an endless rope or chain, set in motion by a gang of men. Where the earth is very dry, screw piles can often be "got down" by very simple means. It sometimes suffices to fix to the upper end of the pile a rod with an eye in it to attach a short iron lever, and screw the pile down. This arrangement will only be available for short depths.

The special advantages of screw piles are considered generally to have more relation to bridge foundations, than any other engineering works, but there is another very important application of the principle which we have as yet only touched upon. It relates to the anchorage of buoys and mooring posts for vessels. Obviously the desideratum in this particular class of works is that the hold or grip of the anchor should be a maximum. In other words, what kind of anchor will give the greatest resistance to a tensile strain, tending to cause it to drag, the anchor itself being of the least weight?

It is a simple question of a combination of maximum hold with maximum weight. About twenty years ago some highly interesting and instructive experiments were undertaken with a view to the practical elucidation of this important point. Some of the best-made anchors, weighing 2 cwt., were dragged along the ground, by a force which produced no effect upon a screwed mooring, inserted to a depth of 3 ft., and weighing only 8 lbs. Others weighing 7 lbs. resisted hauling better than anchors having a weight of nearly 5 cwt. The value of screw piles and moorings for light-house, jetties, breakwaters, and floating signals, and all structures exposed to violent hurricanes and sudden impactive forces, can scarcely be overestimated. On this account they would be found very useful in stormy latitudes, for securely fixing telegraph posts, as it is the commonest occurrence in the world to hear of the telegraphic communication being interrupted in consequence of the posts being blown down. There is one more point relating to screw piles that deserves mention, although probably it is seldom brought into notice. It is the facility with which they can be "drawn." All that is necessary to accomplish this task, which with piles of a different description is a very tedious and laborious one, is to reverse the operation of getting them down—in a word, to unscrew them. It might be stated that when a pile is once down, it is not intended ever to come up again. This assertion is not quite correct, even for permanent works, and certainly incorrect when temporary works are considered. Piles are sometimes required to be drawn in situations when it has been thought that they were down "for good." In works of a temporary nature, where the piles are of timber, they are seldom permitted to be drawn, as the operation would disturb the foundations of the permanent structure, but are cut off near the ground level. If screw piles were employed in temporary dams and such like work, they might be drawn, as the unscrewing would scarcely affect the ground in any sense, and their comparatively small sectional area would still more lessen the chance of any danger. The piles might thus be used over and over again, and constitute a regular item of the contractor's plant. Perhaps the only description of ground that would be unsuitable to the use of these piles would be a stiff clay. The screw would get clogged, and the labor of getting it down would be more than what would compensate the other advantages. Hollow cylinders would be the proper substitute to employ in such a case.

ESTIMATING EARTHWORKS*

By MR. JOHN R. GILLISS.

It is often desirable to make approximate estimates directly from a profile or longitudinal section when lack of time or better data prevent the use of more exact methods. To expedite and increase the accuracy of this work, the following method has been devised:

The ordinary earthwork tables show for any given road bed, or side slope, the quantities in 100 ft. for each foot in height, assuming the ground level transversely. We may take any one of these tables and plot it as a curve, by drawing a horizontal and vertical line, plotting the heights vertically on the same scale as vertical scale of profile or section on which it is to be used, and the quantities horizontally on an assumed scale. 1,000 cubic yards per inch will be found convenient for most work. The diagram is then copied on tracing cloth or horn, and is ready for use.

To get the amount of work between any two stations on a profile or section, lay the diagram so that its horizontal line is parallel to those of the profile, and bisects the grade line at a point; then move it horizontally until the curve passes through some point, which averages the surface line. It is evident that the distance will scale the cubic yards in the prism.

The quantities thus obtained might be read off separately for each hundred feet, by having a scale on the diagram, but there is a much better way. The measuring wheel is simply a wheel about $\frac{3}{4}$ in. in diameter, with a milled edge and turning on a screw. It is mounted in a frame with a straight edge in front to serve as an index. It may be started from either end of the screw, and after measuring any distance, if run in the opposite direction over a scale, will stop when it gets back to the end of the screw it started from, showing the exact distance it had traversed. On this wheel the quantities due to each hundred feet or successive distances are added, and as often as desirable it is run over a scale, the total number of yards noted, and a fresh start made. A wheel, such as that described, will hold about 75,000 yards on the scale assumed.

Having thus given an outline of the process, the details will be more intelligible.

The diagrams for quantities on side-hill work require tables especially calculated for them, showing the cubic yards due to varying heights for each 5 or 10 deg. of transverse slope, as shown below. The curves thus obtained, and due to different transverse slopes, may for any given road, bed, and side slope, be plotted in a single diagram. This enables us to interpolate any intermediate slope by the eye. It will be noticed that both formulæ and diagrams curve the case of side cuts where it is fill on the centre line, and conversely. This is shown in the formulæ by the quantities having a + value for any value of h greater than—$b \times$: and in the diagrams by the curves starting above the horizontal line where the ground slopes transversely and intersecting it at some distance from the origin. To prevent the diagrams from being too long and unwieldly, the curves may be doubled back upon themselves.

If on tracing cloth or paper, the diagrams should be pasted on the back of a rectangular frame of pasteboard or tin; if the latter is used it can be turned up at the edge, and will then be less apt to catch against joints in the paper. The left-hand edge of opening in frame should exactly coincide with vertical line of diagram, that it may serve to stop index of measuring wheel.

The scale for light work where none of the cuts or fills are over 30 ft. may be 400 yards per inch, but when work has places 50 or 60 ft. deep, the diagrams would be too long, and 1,000 yards per square inch more convenient. The scale had best be plotted in the centre of a long strip of paper and laid on the edge of the table when in use.

Similar diagrams can be obtained for culverts, retaining walls and trestles. Box and arch culverts will give straight lines; earthwork, open culverts, and retaining walls will be parabolas with their axes above the horizontal line, and trestles, a series of disconnected straight lines with a break in their continuity at each story in height.

Irregularities in surface line between

*Paper read before the American Society of Civil Engineers, p ril 21, 1889.

two stations can be readily averaged by the eye.

Since the diagrams can be plotted with more accuracy than is generally given to the profile or section, the errors will be principally those arising from imperfections in the latter. The method being one of *mean heights* gives results a little too small. If instead of taking the weights at points half way between consecutive stations, they were taken at even stations, only half the quantity due to first and last station being allowed, the result would be by means of end areas, and therefore too large. The greatest uncertainty arises in assuming the transverse slope where it has not been measured on the ground; this must occur in any method.

These diagrams will be found most useful in balancing cuts and fills, whether it be by alterations of grade on a line already run, or by altering the line when running to a fixed grade, and for making approximate estimates. From 3 to 15 minutes are required to estimate and classify the work per mile. The addition being purely mechanical, it may be carried on for hours without fatigue.

This process may be considered a new method of mechanical integration, and with slight modification will give areas, centres of gravity, and of inertia, etc. Among its applications is the determination of transverse strength of beams of irregular form.

FORMULÆ FOR EARTHWORK TABLES.

Areas.

Let B H F D be the cross section of a cut, and let

$HF=2b$, $CG=h$, $BI=C_1$, $DE=C$, cot. $DFE=\frac{FE}{DE}=s$, tan. $BAI=\frac{BI}{AI}=t$, then $cs+b+\frac{h}{t}=\frac{c}{t}$ $\therefore$ $c(1-st)=bt+h$ $\therefore$ $c=\frac{bt+h}{1-st}$ $\therefore$ $ADF=\frac{b+\frac{h}{t}}{2}\left(\frac{bt+h}{1-st}\right)=\frac{(bt+h)^2}{2(t-st^2)}$ . . . . . (1)

$c_1 s+\frac{c_1}{t}=\frac{h}{t}-b$ $\therefore$ $c_1(1+st)=h-bt$ $\therefore$ $c_1=\frac{h-bt}{1+st}$

$\therefore$ $ABH=\frac{\frac{h}{t}-b}{2}\left(\frac{h-bt}{1+st}\right)=\frac{(h-bt)^2}{2(t+ts^2)}$ . . (2)

$\therefore$ $BHFD=\frac{(h+bt)^2}{2(t-st^2)}-\frac{(h-bt)^2}{2(t+st^2)}=\frac{h^2s+2bh+b^2st^2}{1-s^2t^2}$ . . . . . (3)

Cubic Yards in 100 Feet.

Ground level from (3) $t=o$

$$Q^1=\frac{100}{27}(h^2s+2bh).$$

Side cut from (1) h between $+bt$ and b

$$Q^{II}=\frac{50}{27(t-t^2s)}(bt+h)^2.$$

Thorough cut from (3) h greater than $+bt$

$$Q^{III}=\frac{Q^1+\frac{100}{27}b^2st^2}{1-s^2t^2}.$$

In these equations, after assigning values to b, t, and s, the only independent variable will be h, and since it only enters in its first and second powers, the second difference will be constant, and furnish the most rapid and accurate means of calculating the tables.

Let n be the interval between successive values of h, whose corresponding second difference is required. Giving h an increment n in Q^1, and then subtracting Q^1, we get

$$\triangle Q^1=\frac{100}{27}\{(h+n)^2s+2b(h+n)-h^2s-bh\}$$

$$=\frac{100}{27}(2hns+n^2s+2bn)$$

$$\triangle Q^1=\frac{100}{27}\{(h+2n)^2s+2b(h+2n)-(h+n)^2s-2b(h+n)\}=\frac{100}{27}(2hns+3n^2s+2bn)$$

$$\therefore\ \triangle^2 Q^1=\frac{100}{27}(2n^2s).$$

In a similar manner we get

$$\triangle^2 Q^{II}=\frac{100n^2}{27(t-t^2s)}$$

$$\triangle^2 Q^{III}=\frac{200n^2s}{27(1-s^2t^2)}$$

It is generally unnecessary to calculate the quantities oftener than every 5 ft. after the first five, as the curves become so near straight lines that they can be filled in mechanically.

In cases where it is considered sufficiently accurate to assume the ground level transversely, the foregoing process may be very much simplified.

Assume width of road-bed zero, the side slopes meeting at G. Then let

$BE=h_1$, $EG=h_1$, $BG=h$, and $\frac{BC}{BG}=S$.

$\therefore$ $ACG=h^2s$.

The following table will give cubic yards in 100 ft. for $S=1$.

h.	Q.	h.	Q.	h.	Q.
1′	3.70	10′	370.37	55′	11203.70
2	14.81	15	833.33	60	13333.33
3	33.33	20	1481.48	65	15648.15
4	59.26	25	2314.81	70	18148.15
5	92.59	30	3333.33	75	20833 33
6	133.33	35	4537.04	80	23703.70
7	181.48	40	5925.93	85	26759.26
8	237.04	45	7500.00	90	30000.00
9	300.00	50	9259.26	95	33425.93

The above quantities have only to be multiplied by the ratio S for any other side slopes. Or, if plotted as a curve O A, the curves O B, O C, corresponding to any other side slopes, may be laid off from O G with proportional dividers.

For any width of base, F D = 26, we have only to add h_{11} to the given height h_1, calculate the total area A C G, and subtract area F D G.

Cubic yards in 100 ft. of F D G = $V = \frac{100}{27} h_1, b.$

When b is constant, this is the equation of a straight line O D. The co-ordinates O F, O E, of its intersection O, with any curve O A, represent, respectively, the height h_1, and cubic yards V. If we move the origin of co-ordinates to O, the result will evidently be the same as adding h^1 to height and subtracting V from cubic yards due to sum of heights. We, therefore, have the following simple formulæ:

$$Q = \frac{100}{27} h^3 S, \text{ and } V = \frac{100}{27} h_1, b.$$

The first represents a series of parabolas, one for each side slope, with a common axis and vertex. The second represents a series of straight lines radiating from that vertex, one for each width of road-bed. The intersections of these lines give the new origins from which curves corresponding to any side slope and width of road-bed can be traced.

The preceding method was devised in 1866 to make an estimate on 200 miles of light work on the Central Pacific Railroad.

RAILROAD BUILDING.

From "The New York World."

The recuperating energy and capital of the country are turning into the construction of new railroads, and the extension and perfection of the older lines. Scarcely a corporation now in existence that is not planning or carrying out some project for adding to its business. Among the more prominent of the lines now contemplated or building, are, beginning at the eastward, a line to unite Portland to Halifax, so as to form a part of the short ocean ferry to Europe. Portland is also seeking a direct connection with the lakes and the Mississippi system of roads by way of Ogdensburgh. Massachusetts has her great central line, intended to tap the New York lines by passing through the Hoosac tunnel, and also by the Hartford & Erie, now nearly completed. Connecticut is rapidly completing a new and a shorter line between New York and Boston by the Willimantic link. New York State is building a great line to Oswego—the Midland Railway, which will open up a portion of the State too long neglected. The Southern Central and Long Island Railways are reported to be making fair progress. New Jersey, although her Legislature has narrowly refused the charter for the Air Line road between Philadelphia and New York, has nevertheless, another route to Philadelphia in prospect by an extension of the New Jersey Southern (formerly Britain and Delaware) Railroad from its present terminus at Port Monmouth to a junction with the Newark and New York road at the former place. Pennsylvania is engaged in building several little local roads mainly to reach her coal and iron deposits. At the same time her great Central Railroad Company has finally succeeded in obtaining control of Western connections to Erie, Cleveland, Chicago, Cincinnati, Louisville, and St. Louis, so as to present at this moment the most colossal and formidable railway consolidation in the country, or perhaps in the world. Maryland and Delaware are pushing a line down the eastern shore of the Chesapeake Bay, so as to establish another through line to the South. Virginia has relinquished her state interests in the Chesapeake & Ohio road, and a strong party of New York capitalists are

now pushing forward that line to the Ohio River, which will, within two years, establish a short line between the lower Ohio Valley and the Atlantic ports. Connecting with it are a line from Gordonsville to a point on the Potomac below Alexandria, another from Newport News to Richmond, and a third from Lynchburg to Covington. This activity in Virginia is cheering for the future of that State, and it will be instructive to note which of the candidates for the coming city of Chesapeake—Newport News, Norfolk, West Point, or Acquia Creek—shall first secure a line of ocean steamers for itself. Further south numerous lines are in progress, which is one of the best indications of returning prosperity in that impoverished section. Georgia has its Brunswick and Albany road under way; Florida its Central Railroad projected; Alabama its lines to Chattanooga on the north, and to New Orleans on the west; Louisiana is pushing her line from Brazos to the Texan frontier. In Northern Texas and Arkansas the Memphis and El Paso is making fair progress. Kentucky has a great central line partially constructed to unite Columbus, at her western extremity, with Cattellsburg, at her eastern border, passing through Elizabethtown and Lexington, which, in unison with the Chesapeake & Ohio through West Virginia, will constitute the grand line between the Southwest States and the national capital. Along this central belt are several other lines more or less interwoven with the foregoing; for example: Ohio has a line in contemplation cutting obliquely across her territory from Toledo to the iron and coal regions near Pomeroy; another to connect Cincinnati with Portsmouth, called the Cincinnati & Chesapeake. Indiana, which is already checkered with roads, has an important line constructed from her territorial centre to the central city of Illinois, known as the Indiana and Illinois Central road, begun before the war. Also a short line from Terre Haute to St. Louis. In Illinois, both Chicago and St. Louis are pushing lines down to the Ohio River, so as to tap the rich regions of Western Kentucky and Middle Tennessee; the Chicago & Vincennes being the project of the former city, and the St. Louis & St. Joseph westerly, as the protegé of the latter. Both roads pass through coal fields. Connected with this same belt of new lines reaching from the Potomac to the Mississippi are extensions in Missouri. The St. Louis & St. Joseph and the St. Joseph & Denver form the two essential links in the chain of direct railroad communication to the far West, which, by avoiding the circuitous route from Omaha, will have a great advantage hereafter, as the Union Pacific Company cannot, by its charter, discriminate against any of its Eastern connections, receiving the Government subsidies. Iowa and Minnesota are being gridironed by new roads. In Nebraska and far-distant California and Oregon, new roads are building with extraordinary rapidity also.

The inference to be drawn from this general activity is a flattering one. It takes money to build railroads, and surplus capital, instead of venturing against the risks of commercial business, or the still greater dangers of real estate inflation, is in large part turning to the improvement of our great system of railroad communication. These roads are built in part upon mortgage bonds, which are based upon pledges of the property. Though these railroad bonds are placed in the hands of Wall street bankers for sale, dealings in them are not to be confounded with the ordinary stock-gamblings of that locality. Railroad bonds differ in that regard from railroad stocks, although both are liabilities of the railroad corporations; the bonds have to be taken care of, though the stock may be neglected. Even the most recklessly managed roads have generally so scrupulously provided for their bonds that they are accounted as safe and convenient for permanent investments as liens on real estate.

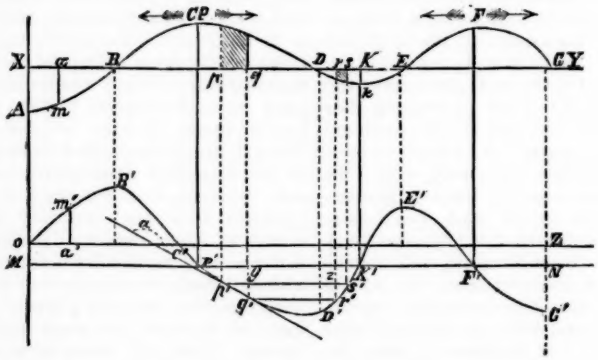
Wire-rope Tramways.—It appears that the method of transport by wire-ropes, which was tried on an experimental line near Leicester last year, has made considerable progress since that time. Thirteen lines, varying from short distances to 4 miles in length, have been constructed, and upwards of 100 miles are in course of preparation or under contract.

Six thousand nine hundred workmen at the iron and steel works at Krupp, in Germany, produced 125,000,000 lbs. of steel last year.

CUTTING AND FILLING.

From the "Polyt. Tiddschrift de Christiana," through "Annales du Génie Civil."

The profile of the road is represented by $A, B, C, D, E, F, G,$; $X\ Y$ is the grade line. Take an arbitrary axis, $O\ Z$, parallel to $X\ Y$ and lay off upon it as ordinates masses of earth, then the ordinate $a'm'$ will represent the quantity of earth needed for filling between the profile $A\ X$ and $a\ m$; the ordinate B' representing the filling between the profiles $A\ X$ and B. Considering the fillings as positive and the cuttings as negative, it is obvious that the ordinates increase as long as there are fillings ; that is to B, and begin to diminish when cutting is necessary. At the point C the ordinate is zero, for cutting and filling are equal. When there is more cutting the ordinates become negative, and reach a maximum at D', where filling begins again. In this way we obtain a curve $O\ B'\ C'\ G'$. Regarding a part $p'\ q'$ as a straight line, and denoting by a the angle formed by $p'\ q'$ with the axis, we have tan. $a = \frac{M}{l}$; M being the cutting between p and q and l the distance $p\ q$. As a is obtuse, tan. a is negative, which shows that M is a cutting. If the distance $p\ q$ is very small, a is the angle between the tangent and the axis, and the greater the value of tan. a, the greater the mass of cutting or filling at the point under consideration. If the profile of the road is



constant, the curve becomes a straight line.

Draw an arbitrary line $M\ N$, and let $P'\ K'\ F'$ be the points of intersection of the line with the curve. These points show how the earth should be moved so that cuttings and fillings may balance. The cutting between P and D is of exactly the same volume as the filling between D and K. $P\ D$ can therefore be moved to $D\ K$. So the mass between the profiles F and E corresponds exactly to the cutting between E and K. At the extremities there would doubtless be a difference between the two, so that different methods are required here. The line $M\ N$ which fixes the points to which the earth should be moved is called the line of level (*ligne de niveau.*)

The surface between the curve of cutting and the line of level represents the product of the mass of earth to be moved by the distance of transportation.

Consider, for example, the earth between two adjacent profiles p and q ; this strip is represented by $y\ q'$. Draw $p's'$, $q'r'$ parallel to the axes ; then $z\ r' = y\ q'$; and $z\ r'$ represents the mass $r\ s$ of filling ; $p\ q$ can then be used to fill $r\ s$ and is carried to $p's'$. The surface $p's'r'q'$ represents the product of the mass $p\ q$ by its distance ; and as this holds for all parts between P and K, the surface $P'\ K'\ D'$ corresponds to the product of the mass to be carried from $P\ D$ to $D\ K$ by its distance. As the expenses of transport are proportional to the product of masses by distances, these will be proportional to the surfaces between the line of level and the curve of filling.

If an exact expression of the cost of transport is desired it can be put under the form :

$$K = I\,a\,M + \Sigma\, e \triangle M$$

in which a and b are constants depending on the kind of transportation, M is the mass of earth to be moved, and e the distance. As M is constant, $\Sigma\, e \triangle M$ is the variable which represents the surface of the curve.

If the expense is to be a minimum, then $\Sigma\, e \triangle M$ must be the least possible. The problem is equivalent to this ; to draw the line $M\,N$ so that the surface shall be a minimum: Draw a new line of level $O\,Z$ at a distance $\triangle x$ from the first ; let $M\,P' = l_1$, $P'\,K' = l_2$, $K'\,F' = l_3$, $F'\,G' = l_4$; $F =$ total surface ; then

$$F + \triangle F = F + \triangle + (l_2 + l_4 - l_1 - l_3).$$

In order that F may be a minimum it is necessary that $\triangle F = O$, hence $l_2 + l_4 = l_1 + l_3$. The parts of the line above the mean line should be equal to those below.

EXHAUST STEAM FOR HEATING PURPOSES.

By CHARLES E. EMERY.

From "The American Artisan."

Questions are frequently asked regarding the relative economy of heating buildings with live steam taken direct from the boiler, or with the exhaust steam from a non-condensing engine.

Though the steam-engine is a *heat* engine, the best examples utilize only 10 per cent. of the heat in the steam used, consequently at least 90 per cent. of the heat which enters the cylinder escapes with the exhausting steam, and can be made available in no way except for heating purposes.

The temperature of the exhaust steam from a condensing engine is from 130 to 140 degs. Fahr., and that from a non-condensing engine is from 212 to 220 degs. and upward, varing according to the amount of back pressure in either case. A portion of the escaping heat is generally utilized in heating the feed-water for the boiler. In the condensing engine the low temperature of the exhaust steam and the liability to air leakages and loss of vacuum in long pipes, make it impracticable to save any more of the heat than that mentioned, and the remainder is necessarily wasted in heating the condensing water. In the non-condensing engine there is on the average 10 per cent. of the heat utilized by the use of a feed-water heater, in addition to the 10 per cent. transmuted into work, conseqently 80 per cent. of the original amount of heat remains in the exhaust steam and is usually wasted in the atmosphere. If this large quantity could be used for heating buildings without interfering with the performance of the engine, there would be no doubt of the value of the system—the heat in fact would cost nothing; but it is evident that in order to cause this steam to traverse through heating-pipes and coils it must have sufficient pressure in excess of that of the atmosphere to enable it to overcome the increased resistance. The additional pressure varies from 2 to 5 lbs. and upwards per sq. in., and acts as so much back pressure upon the piston, thereby reducing the power of the engine. The power lost must be supplied by increasing the mean pressure upon the driving side of the piston, and the question becomes: What is the relative cost in fuel of supplying the heating-pipes with steam direct from the boiler, as compared with that required for the extra power necessary to circulate the exhaust steam through the building ?

The answer to this problem depends upon the particular circumstances of each case, and to make the subject generally understood, it is first necessary to investigate some of the known facts in regard to low-pressure steam-heating apparatus.

Manufactories where steam-power is employed generally have a large number of windows for the convenience of the workmen, and are often more or less exposed to cold draughts from hoistways, staircases, and outer doors; and though the temperature need not be so high as in dwelling-houses, it would be unsafe to allow less than one square foot of heating surface in the heating-pipes and coils to every one hundred cubic feet of space to

be heated. In order to form a safe estimate of the amount of fuel required when the steam is taken direct from the boiler, we may assume as an extreme case that the difference between the external air and that of the room is to be 69 degs.; then, according to the experiments and formula of Tredgold, we find that it will require $3\frac{1}{8}$ sq. ft. of surface to condense a pound of steam per hour, and if 1 lb. of coal evaporate 8 lbs., of water, it will supply steam to ($8 \times 3.125 =$) 25 sq. ft. of heating surface, and will heat ($25 \times 100 =$) 2,500 cubic ft. of space for one hour. The estimate will be correct for average circumstances, but will not apply to all cases of low-pressure steam-heating, especially where the rooms are unusually exposed either to draughts of air or great extremes of temperature.

The cost of heating by exhaust steam may be measured by the amount of coal required to produce the power necessary to overcome the increased back pressure. We have seen that in ordinary cases 1 lb. of coal per hour will heat 2,500 cubic ft. of space. If, therefore, in a given instance, 3 lbs. of coal are required per horse-power per hour, then for every horse-power expended in distributing the exhaust steam through the building, there should be at least three times 2,500, or 7,500 cubic ft. of space heated.

In estimating the greatest amount of space that can be heated by the exhaust steam of an engine, it should be borne in mind that the quantity of steam discharged necessarily varies with the work being done, and as the temperature of the building requires to be constant, we can only utilize the quantity of heat escaping when the engine is lightly loaded. For instance, an engine of 80 horse-power may be loaded occasionally to only 40 horse-power for half an hour or more at a time. If each horse-power require on the average 3 lbs. of coal per hour, 40 horse-power will require 120 lbs. As has been before mentioned, the exhaust steam from an engine contains $\frac{8}{10}$ of the heat received from the fuel, so in the present case the maximum heating effect is equal to $\frac{8}{10}$ of 120 lbs., or 96 lbs. of coal per hour; and as each pound of coal will heat 2,500 cubic ft. of space, 95 lbs. will heat 240,000 cubic ft., equal to the capacity of a building 100 ft. long, 60 ft. wide, and 40 ft. high. The extra power required to overcome the back pressure in that sized engine could not well exceed 10 horse-power, which would cost 30 lbs. of coal per hour; and as 96 lbs. would be required were steam taken direct from the boiler, the saving is ($96 - 30 =$) 66 lbs. per hour, or 68 per cent. If the quantity of space heated be less than that mentioned, the percentage of saving will be less; for instance, to heat 150,000 ft. of space in the ordinary way would require 60 lbs. of coal per hour; but with the exhaust steam in the above instance the cost will still be 30 lbs., so the saving will be 50 per cent. In warm days in winter, when less heat is required in the buildings, the same power will be taken from the engine to supply the less quantity of heat, so that the percentage of saving will be less. There would be some saving, however, whenever it required more than 30 lbs. of coal to heat the rooms. In case each horse-power required more coal per hour than that stated, the advantages of exhaust heating would be correspondingly diminished, unless the size of the engine and amount of power necessary to distribute the steam were also less. In some instances, probably, the system is productive of loss as compared with the use of live steam, so the true plan is to make accurate calculations in each case. The following directions may therefore assist many readers:

To ascertain whether heating by exhaust steam is economical where it has already been applied, the first step is to measure the extra back pressure on the piston, which can be done by indicating the engine when the steam is escaping freely into the atmosphere, and when the exhaust is throttled for heating purposes, and comparing the back pressures shown by the diagrams. If this be not convenient, one leg of an inverted glass siphon containing mercury may be connected to some enlargement of the exhaust-pipe, and the mean difference in level noted in the two cases the same as before. One pound pressure corresponds to about 2 (2.037) in. of mercury. A longer siphon filled with water may be used with some inconveniences. In such cases, 1 lb. pressure corresponds to a column of water 2.3 ft. high and 60 deg. temperature, or 2.4 ft. high at a temperature of 205 deg.

Having ascertained the extra back pressure, the horse-power required to overcome it may be ascertained by the follow-

ing rule, viz. : Multiply together the back pressure, the area of the piston in square inches, and the speed of piston in feet per minute, and divide the product by 33,000.*

The next step is to ascertain the coal required per horse-power per hour. This should be done, when practicable, by regular experiment. In other cases, it may be assumed that engines working with a steam pressure of 50 lbs. and under, with little expansion will require 5 to 6 lbs. of coal per horse-power per hour. With more expansion, 4 to to 5 lbs. will be required ; and the most improved form of expansive engines, working with steam at 80 lbs. pressure, will furnish a horse-power for 3 lbs. of coal per hour. By multiplying the horse-power due to the increased back pressure by the coal required per horse-power per hour, and the product by 2,500, the result will be the least number of cubic feet of space which can be heated economically by the exhaust steam from that engine. The advantages under different circumstances may be ascertained in the manner previously stated.

In heating a building by exhaust steam particular attention should be given to the size and arrangement of the pipes. A main exhaust pipe should be run up through the building and out of the roof in a usual manner. This pipe should be larger than is ordinarly employed, so as to form a kind of expansion chamber to equalize the exhaust pressure. In summer, the top of this pipe should be open, but in winter it should be covered with a flat valve faced with wood or rubber, fitted so that it can be moved with little friction, and weighted to the pressure required to circulate the exhaust steam, which will usually be less than 3 lbs. per sq. in. This vertical pipe may be made of cast-iron, and the ordinary socket joints with lead filling will answer, provided care be taken to sustain the weight of the pipe wholly at the bottom, so that all other parts are free to expand upward when heated, at the rate of one-eighth of an inch.

* Many engineers will find the following formula more convenient.

$$\text{H. P.} = \frac{d^2 srp}{252{,}000}$$

which, put in the form of a rule is : Horse-power equals the square of the diameter (d) in inches, multiplied by the length of a single stroke (s) in inches, multiplied by the number of revolutions per minute (r), multiplied by the extra back pressure (p), and divided by 252,000.

to every 8 ft. in length. From the vertical exhaust pipe the heating pipes may be led out for each floor of the building. A common plan is to put a good-sized cast-iron pipe under the work-benches along the sides of the rooms. Such pipes should be connected by bolted flanges, and ample provision made for expansion and contraction. Heating coils of the ordinary construction may also be used, care being taken to make the leading pipes wiih as few bends as possible and of sufficient size. To obtain the proper size of pipe for a given case, the following formula may be used, which is founded on some experiments made by the writer for the United States Government, viz. : $a = W \div 46\ (p + 3)$ in which a= area of steam-pipe in square inches, W the weight of steam in pounds delivered per hour, and p the difference in pressure. Assuming as an extreme that 2.4 sq. ft. of surface (s) will condense 1 lb. of exhaust steam per hour, then, when the difference in pressure equals 1 lb., $a = s \div 440$. The following is then a safe rule:—Divide the heating surface in square feet by 400, the result is the proper area of the pipe in square inches. The following table gives the amount of surface which will be supplied with steam through pipes of the sizes mentioned:

DIAMETER OF PIPE.		AMOUNT OF SURFACE.	
¾	inch	40	square feet
1	"	75	"
1¼	"	170	"
1	"	300	"
1½	inches	480	"
1½	"	700	"
2	"	1200	"
2½	"	1900	"
3	"	2800	"

The pipes should be slightly inclined so that the condensed water will move in the same direction as the steam. The ends of the various heating-pipes and coils should be connected with a water-pipe terminating near the boiler in an inverted siphon, the shorter leg of which should be about 7 ft. long. The bend may extend under ground if necessary. This siphon should deliver the condensed water into a tank where it can be returned to the boiler. An air-cock should be placed in the water-pipe to allow the air to escape in starting.

Arrangements should be made so that the exhaust steam can be shut off from each room separately by a valve, and in

some instances it may be desirable to admit live steam into portions of the pipes when the engine is not in motion.

It is believed that the system of heating by exhaust steam may be applied with advantage in nearly every establishment where a non-condensing steam-engine is in use.

THE FAIRLIE ENGINE TRIALS.

From "Engineering."

The following details of experiment with the Fairlie engines, "Progress" and "Little Wonder," upon the Mid-Wales Railway, and the 1 ft. 11½ in. Festiniog line, will be found of interest, and go to prove all that we have advanced in favor of the system. The performance of the engines must have satisfied the members of the Imperial Russian Commission who were present, of their value, especially upon steep gradient lines, with sharp curves, such as those on the Festiniog Railway.

THE FAIRLIE ENGINE ON A 1 FT. 11½ IN. GAUGE, COMMONLY CALLED 2 FT.

The Result of Experiments on the Festiniog Railway, on February 11 *and* 12, 1870.

Feb. 11.—Started from Portmadoc with the "Little Wonder," or Fairlie engine and

	tons.	cwt.	qrs.
90 slate wagons	57	10	0
7 passenger carriages and vans	13	10	0
57 passengers	4	0	0
	75	0	0
Engine	19	10	0
	94	10	0

Engine, double bogie, $8\frac{3}{16}$ in. cylinders × 13 in. stroke.
Wheels, 2 ft. 4 in. diameter.
Pressure of steam, average 150 lbs.
Steepest gradient, 1 in 74.
Sharpest curves, 1¾ chains.

The total wheel base is 19 ft., the wheel base of each bogie is 5 ft., and the total length over all, 27 ft.

On sharpest curves and steepest gradients, with engine in full gear, average speed 14½ miles, exclusive of time lost in stopping and starting. Length of train, 854 ft.

Generally observed that, even on curves of 1¾ chains radius and at maximum speed, there was very little perceptible oscillation or movement on the engine, or in the carriages, and by no means such as is usually felt, even on comparatively easy curves on ordinary railways, and less at high speed than at low speed. The superelevation of the outer rail on the sharpest curves was 3 in.

February 12.—Experiments with "Little Wonder," 19½ tons; "Welsh Pony," 10 tons; "Mountaineer," 8 tons, to test steadiness of running on Frath Mawr Embankment.

On the "Welsh Pony" and "Mountaineer" strong vertical oscillation with less lateral oscillation.

On the "Little Wonder, when riding on the footplates, no perceptible vertical or lateral oscillation, but a smooth floating movement when riding on the bogie frames, slight lateral oscillation, but less than on the other engines.

The oscillation of the Fairlie engine being confined to the bogie, the influence of impact on the rails from the flanges of the wheel was far less than in the case of the "Pony" or "Mountaineer," the whole weight of these engines being brought to bear in the course of their oscillations upon the rails.

In all the above cases the speed was confined to 10 or 12 miles an hour on a straight line on a gradient of 1 in 1,200, and the line was laid with rails weighing only 30 lbs. to the yard, not fished at the joints.

The "Welsh Pony" engine, weighing 10 tons, with cylinders $8\frac{3}{4}$ in. diameter, by 12 in. stroke, and with wheels 2 in. diameter, took 50 wagons loaded with slate from Portmadoc to the engine house, and stopped on a gradient of 1 in 85, unable to proceed further with 160 lbs. to the square inch of pressure:

	tons.	cwt.	qrs.
Weight of 50 wagons loaded	123	10	0
Passengers	3	10	0
	127	0	0
Engine	10	0	0
	137	0	0
The "Welsh Pony" then took 25 wagons weighing	59	7	2
Passengers	3	10	0
	62	17	2
Engine	10	0	0
	72	17	2

and mounted 1 in 85 with 140 lbs. pressure of steam in starting, and 130 lbs. after running about ¼ of a mile, when she was stopped to return.

The same engine then tried with 30 wagons could not start on a gradient of 1 in 85, but the engine wheels did not revolve there; there was, therefore, no want of adhesion. The load having been reduced to

	tons.	cwt.	qrs.
26 wagons weighing	62	6	0
Passengers	1	10	0
	63	16	0
Engine	10	0	0
	73	16	0

with an average pressure of 150 lbs to the square inch, the "Pony" took them up 1 in 85 for a ¼ of a mile at 5 miles an hour, until she was purposely stopped.

The "Little Wonder" left Portmadoc the same afternoon with 72 loaded wagons weighing

	tons.	cwt.	qrs.
Slate trucks	138	17	2
Empty wagons	43	13	0
Passengers	4	0	0
	186	10	2
Engine	19	10	0
	206	0	2

Started with 165 lbs. of steam pressure and ran to the engine-house, and up the above gradient of 1 in 85, and was purposely stopped with steam at 125 lbs., and a low fire. Through the misapprehension of the engine driver, she was then backed down to the locality from which the "Pony" had started with 26 wagons, and the fire having been made up and steam raised to 170 lbs., she started freely, occasionally slipping, attained to a speed of 5 miles an hour with the 72 wagons, and after running about ¼ of a mile she was increasing speed on a gradient of 1 in 100, when she was purposely stopped with steam pressure of 170 lbs. to the inch.

In the above experiments the shorter trains were standing when they were started or attempted to start, partly on a curve of 4½ chains, and in the last experiment with the "Little Wonder," the train having been longer, it stood partly on a curve of 4½ chains radius, and partly on a reverse curve 8 chains radius. The length of this train was 648 ft.

The weather was fine, with a strong cold wind blowing against the trains, and the rails were in a remarkably good state for adhesion.

The slate wagons had no springs; the diameter of their wheels was 1 ft. 6 in., and that of the journals was 1¼ in.

The above report was signed by the Duke of Sutherland, Count Alexis Bobrinskoy, President of the Russian Commission; Lieutenant-General Sir Wm. Baker, R. E., K. C. B.; W. T. Thornton, Corresponding Secretary of Public Works Department, India; Juland Danvers, Official Director of Indian Railways; and Captain H. W. Tyler, Board of Trade.

SECOND SERIES OF EXPERIMENTS WITH THE FAIRLIE ENGINE ON THE 1 FT. 11½ IN. GAUGE.

The Result of an Experiment on the Festiniog Railway, on the 16th of February, 1870, with the "Little Wonder" (Fairlie Engine).

DESCRIPTION OF LOAD.

	tons.	cwt.	qrs.
22 wagons of coal	64	18	0
21 wagons of slates	49	3	1
2 bogie timber trucks [carrying timber in length 42 ft.]	4	18	2
Passengers' weight	1	1	2
2 empty trucks between timber bogies	1	4	1
1 workmen's carriage	0	12	0
Engine	19	10	0
Total	141	7	2

Length of train with engine.....407 ft.

The whole distance to be run over from Portmadoc to Dinas, 13¼ miles, having a total rise from sea level of 703 ft., with maximum gradient of 1 in 74, and average gradient of 1 in 92 for 12¼ miles, the Traethmaur Embankment and Portmadoc of 1 mile in length being practically level. The maximum curves, 1¾ chains.

Average curves being 6.7 and 8 chains. The whole of the line being composed of a succession of curves with the exception of the before-named embankment, and three or four other short portions.

The train started from Portmadoc at 5.41 P. M. At Penrhyn Station, 5.58 P. M., without stopping there.

Arrived at Hafod Llyn Station at 6.18 P. M., where it stopped 8½ minutes.

Started at 6.26½ P. M., arrived at Ddu-allt Station (watering place) at 6.40 P. M., stopped 15 minutes on account of water being frozen, the tank could not be filled in the usual time.

The train reached the long tunnel at 7.2

P. M., through which it passed in 2 min. 10 sec. (length of tunnel 730 yards). Ran up to Tanygrissian Station, at which it arrived at 7.9 P. M., passed it slowly without stopping, arriving at Dinas at 7.15 P. M., having made the entire journey in 1 hour, 34 min., including stoppages, or exclusive of stoppages, 1 hour 10½ min.

Maximum speed.....15 miles an hour.
Average speed .....11¼ " "

The engine during the journey from Portmadoc to Hafod Llyn without slipping.

On starting from Hafod Llyn Station, a slight slipping occurred (the train being on a curve of 4 chains, with an inclination of 1 in 110), the rails being wet and greasy.

Slight slipping on starting from the watering place at Dduallt.

The engine slipped three times in passing through the tunnel, the rails being wet throughout.

Considerable slipping took place at the junction of branch line, this place being always wet and greasy, owing to the slate trains waiting for the down passenger train.

The pressure of steam ranged from 160 to 180 lbs., at which latter pressure the train started, the pressure being on one occasion only 145 lbs., for a quarter of a mile average pressure 175 lbs.

The entire journey was run throughout by the engine in "two-thirds gear."

There was a head wind during the whole of the journey, such being very strong in some parts of the line against the train.

Signed by Livingston Thompson, C. E. Spooner, Count Alexis Bobrinskoy, T. Rocheberg, Professor Saloft, R. Vandesen, J.Sementschinoff.

Third Series of Experiments with the Fairlie Engine on the 1 ft. 11½ in. gauge, under the Superintendence of the President and Engineer of the La Vendée Railway of France.

Started with a train of 140 empty slate wagons and 7 loaded coal wagons ; gross load, 100 tons 16 cwt. 2 qrs.; length of train, 1,323 ft.; maximum speed, 16½ miles; average 12½ miles.

And on the return journey, the speed attained was 30 miles an hour over many portions of the road, the minimum being 25 miles.

THE FAIRLIE ENGINE ON THE 4 FT. 8½ IN. GAUGE.

Experiments on the 14th and 15th February, 1870, with the "Progress" Locomotive Engine.

The "Progress" is a double bogie engine with a four-wheeled bogie under each end. The cylinders are 15 in. diameter, by a stroke of 22 in. The wheels are 4 ft. 6 in. diameter, and are coupled together in both bogie frames, so that all the wheels of the engine are driving. The wheel base is 22 ft. The grate area is 19½ ft. The heating surface is, in the firebox, 92 ft., and in the tubes, 1,901 ft., making a total of 1,993 ft. The diameter of the boiler is 4 ft. 2 in., and the tubes are 388 in number, and 2 in. in diameter, outside measurement. The total length of the boiler is 24 ft. from tube plate to tube plate of the two smoke boxes respectively. The length of the tubes is 9 ft. 10 in. The total weight in working order, when the engine is fully equipped, is 54 tons, including 1 ton 15 cwt. of coal and 2,000 gallons of water. The engine is fitted with the steam brake of M. LeChatelier, and with an ordinary brake applied to all the wheels. The extreme length from buffer to buffer is 32 ft.

On the 14th February the "Progress" left the Three Cocks Junction of the Mid-Wales Railway with 39 loaded wagons and 3 brake vans, and about 50 passengers and workmen, making a total weight, exclusive of engine, of 472 tons 6 cwt. 2 qrs. It measured 710 ft. in length, besides the engine. It started from the Three Cocks at 3.6 P. M. with 130 lbs. of steam, as indicated by a Bourdons gauge. She proceeded freely from a gradient of 1 in 2,215. She passed two rising gradients of 1 in 75, the latter 29 chains long, and with the above pressure, but she slipped twice on a third gradient of 1 in 75, 34 chains long, and on reverse curves. After passing that gradient without difficulty, and a gradient 1 in 162, she came to a stand within 50 yards of the summit of a gradient of 1 in 90, 21 chains long. The steam pressure was then 120 lbs. to the square inch. The water having fallen to near the bottom of the gauge glass, Mr. Fairlie, who was driving the engine, and was unacquainted with the gradients, applied both injectors

about 30 chains from the point where the engine pulled up at 3.35 P. M. The total distance run was 6½ miles in 29 minutes.

There was a strong wind blowing across the train, with hoar frost, and the rails were in excellent condition. The axle-boxes of the wagons had been greased in the ordinary way. The engine was unable to start the train after it stopped, though the pressure had been increased to 150 lbs.

On the 15th of February the "Progress" left the Three Cocks at 10 hours 47 min. 30 sec., with 140 lbs. of pressure, and with a load of 40 wagons, and 2 vans, and about thirty passengers. The train was 720 ft. exclusive of the engine, and weighed altogether 475 tons 16 cwt. 2 qrs.

She proceeded freely to the water tank, 3 miles from the Three Cocks, and stopped there at 11 hours 0 min. 30 sec., with 115 lbs. of pressure. But the tank having been partly frozen, no additional water could be obtained by the trough. She started again at 11 hours 6 min. and 30 sec., with 125 lbs. pressure, and went straight forward to Builth, passing Erwood, 7 miles from the Three Cocks, at 11.27 P. M. She reached Builth, 14 miles from the Three Cocks, at 11 hours 50 min. 30 sec., with 100 lbs. of pressure, it being level for the last mile to Builth the engine fire was lowered and the boiler pumped full of water. She did not stop between Three Cocks and Builth. She passed the point at which she had stopped on the previous day, at 8 miles an hour, and with a pressure of 140 lbs. to the inch. The engine on this day was driven by Edward Williams, under the supervision of Mr. Greenhow, the locomotive superintendent of the Mid-Wales Railway.

On the 15th February the "Progress" left Tall-y-llyn at 2 hours 51 min. 30 sec., with 13 loaded wagons and 2 brake-vans, and with a steam pressure of 125 lbs. After running for three miles for the most part a descending gradient of 1 in 40, she was brought to a stand at Taly-bont Station, where her tanks were filled. She started from Taly-bont at 3 hours 13 min. with a pressure of 140 lbs., and ascending a gradient of 1 in 35 for half a mile. She then mounted a gradient of 1 in 38 for 6⅝ miles, and passed the summit of that gradient at 4 hours 16 min. 15 sec., with 120 lbs. of pressure, she passed through the tunnel 660 yards long as a rising gradient of 1 in 68 in 2 min. 15 sec., and was stopped at the Torpantau Station at 4 hours 18 min. 30 sec., the pressure continuing the same. This portion of the line contained curves of 12.16 and 20 chains radius, as the rising gradient of 1 in 38, the train having sometimes been passing over reverse curves.

The water gauge burst at 4½ miles from Taly-bont, and the engine driver, Edward Roberts (who was acting under the superintendence of William Barker), was without any means of ascertaining the state of the water in the boiler, inasmuch as there were no steam cocks on the boiler. The engine did not slip at all on the 15th. The weather was fine and dry as on the 14th, but with more sunshine and rather less wind.

MATERIALS FOR CONSTRUCTION IN EUROPE.

We abstract from Commissioner Blake's Report,* the following statements regarding the materials used in engineering structures in middle and western Europe:

Among the hard stones worked in France are the syenites, granites, and porphyries of the Vosges, the green melaphyre of Tournay, the granites and protogines of Mont Blanc. The jaspers of St. Gervais, near Mont Blanc, are attracting much attention for their beauty and novelty. The quantity is supposed to be inexhaustible, and blocks of large size are obtained. The rock is believed to result from the metamorphism of a bed of sandstone of the Triassic period.

It is banded and brecciform in structure, and presents a great variety of colors most capriciouly mingled, the most conspicuous being blood red, rose, and green. It is traversed by veins of white

* "Civil Engineering and Public Works," by William P. Blake, Commissioner of the State of California.

quartz. These beautiful jaspers were represented at the Exposition by two splendid columns at the entrance of the glass-house for the equatorial plants. Similar columns have been placed in the new Opera House. The cost of the stone is 1,500 francs the cubic metre at the quarry, and 200 francs delivered in Paris, but it is supposed that when the quarry is fully opened the price will be reduced.

Of marbles France has a bountiful supply. They are obtained chiefly in the Vosges, the Alps, and Pyrenees, and from Boulogne and the Jura. Quarries at the last-named locality are regularly worked on a large scale, and blocks are furnished at low prices.

The French section contained a great many beautiful marble columns designed for the new Opera House. The marbles came from the quarries of Sarrancolin (Hautes-Pyrenees), St. Beat (Haute-Garonne), Félines (Hérault), St. Antonin (Bouches-du Rhone), Porcieux (Var), Jeumont (Nord).

According to the French customs returns, the exportation of French marble, which was valued at only 350,405 francs in 1855, constantly increased until the value had reached 1,140,279 francs in 1866. The importation of marble has also increased regularly during the same time, being valued at 1,038,271 francs in 1855, and at 2,357,115 francs in 1866. The disposition to use marble in construction is increasing in France.

The following figures show the prices in francs per cubic metre of the marble most in use in France during 1867. These figures and the preceding relating to the marble industry of France are compiled from the Report of Prof. Delesse :

Sarrancolin	1,012
Campan mélange and Campan vert	1,232
Rosé clair	792
Griotte d'Italie	1,012
Griotte œil de perdrix	1,117
Languedoc	792
Brèche Imperiale	682
Vert de Maurin (serpentine)	1,122
Brocatelle jaune, violette ou jaune fleurie	847
Sarrancolin de l'ouest	572
Henriette	627
Noir française	374

The display of marbles from Italy was peculiarly fine, remarkable alike for the beauty of the material and for the liberality and taste displayed in the selection of the specimens. They were in blocks a foot square and beautifully polished. The institute Technico de Firenze also sent a splendid series of specimens of all varieties of the Italian building stones, among them a series of sixty polished blocks of serpentine of as many different shades and colors.

From Algeria there was a fine collection of some 400 specimens, in cubes measuring 6 inches on a side, of the building stones of that country. These were collected by the "Service du genie militaire, des ponts et chaussées." The series contained a great variety of marbles, among them the beautiful light-colored "onyx marble," so-called, now much prized and used for interior decoration in France.

Belgium is extremely rich in marble of various colors, particularly the much esteemed black marbles. They are obtained in the provinces of Namur, Liege, and of Hainaut. Of the black marbles, those of Denée and of Furnaux are much exported to France, Germany, and Italy. The fine black marble of Golzinnes is nearly all sent to Paris. The black marble from the quarries of Peruwelz and of Basècles (Hainaut) is very solid, and is exported in considerable quantities to all parts of Europe and to America.

There are 90 marble quarries in the province of Namur ; they employ nearly 806 men, and the value of the annual production is estimated at 860,000 francs. The quarries of Wellin yield nearly 400 cubic metres of marble annually, of a value of 40,000 francs. It is estimated that not less than 3,000,000 francs of capital is invested in the marble industry of the province of Namur alone.

But Belgium is rich in quarries of all kinds of building stone ; not only marbles, but granite, paving stones, sandstone and slates.

The marbles of Algeria were well represented at the Exposition, particularly the "marble onyx" from quarries worked formerly by the Romans. It is beautifully veined in parallel layers like onyx, and appears to be of stalagmitic origin. It resembles the Mexican stalagmitic marble. Fine specimens of onyx marble were shown also in the Russian section.

From Scotland and from Cornwall there were several very finely wrought specimens of granite, and from Sweden a fine display of the porphyry of Elfdalen. In the Bavarian section there were two fine vases of a green dioritic porphyry.

The following table shows the weight in kilogrammes, per cubic metre, of some of the various stones employed in the construction of the new Grand Opera House of Paris, and the pressure per square centimetre which each will sustain before crushing.

Weight and strength of some of the varieties of stones used in the construction of the Grand Opera House.

Description of Stone and Locality.	Weight.	Crushing Weight.
Jasper of Mount Blanc, St. Gervais	2,716	1,839
Brown granitoid porphyry Bazoches	2,585	1,487
Green porphyry (melaphyre).	2,855	1,111
Red granitoid porphyry, Autun	2,585	1,080
Porphyroidal granite, St. Martin du Puy	2,567	1,077
Micaceous granite, Lormes	2,694	1,077
Red syenite, Servance	2,654	901
Syenite ("feuille-morte"), Servance	2,683	867
Porphyroidal granite, Servance	2,643	715
Marble ("sanguin") Sampans, Jusa	2,637	1,076
Marble (violacé)	2,663	994
Pierre de Damparis, Jura	2,683	898
Pierre de l'Echaillon, Commune de Rivière	2,726	852
White Echaillon, St. Quentin	2,529	781
Yellow Echaillon, Lignet	2,686	777
Rose-colored Echaillon	2,472	606
Pierre de Anstrude, Yonne	2,261	365
Soft stone, Yonne	2,161	369
Pierre de Ravières	2,157	377
Grès bizarré, Lutzelbourg	2,130	215

CEMENTS AND ARTIFICIAL STONES.

Cements were exhibited in great variety from France and Belgium, not only in the crude and commercial state, but worked up into various objects and moulded into blocks of a form suited for testing by pressure and weighting.

One of the most interesting displays was made by the French Cement Company of Boulogne-sur-Mer, which received a gold medal. An apparatus for testing the strength of cements was included in their exhibition. Blocks of the hardened cement, about 8 inches long and shaped like a stout letter **I**, were placed between strong iron clamps, and made to form a link in the chain by which a heavy platform was suspended. Upon this platform below, heavy weights were piled nearly to the limit of the strength of the slender neck of the cement block. One of these blocks, formed of 4 volumes of sand and 1 of cement, and 1½ in. square, sustained a strain of 900 kilogrammes. Another one, four inches square, composed of 2 volumes of sand and 1 volume of cement, sustained a weight of 1,200 kilogrammes. The sand used in these experimental blocks was very coarse, nearly as large as beans or peas. Another method of showing the strength of their cement was by building a column of brickwork about six feet long, extending horizontally like an arm, and supported at one end only.

This cement is artificially prepared by mixing intimately and with great care 79½ per cent. of carbonate of lime, in powder, with 20½ of clay, and then burning at a high temperature. There are now many establishments in France, Prussia, Germany, Austria, and Russia, where enormous quantities of excellent cement are manufactured. In one of the establishments recently started in France, at Pouilly, the method consists in crushing together two kinds of argillaceous limestone from the Lias; one containing 43.5 per cent. of lime, the other a belemnitic limestone, which contains 48 per cent. of lime. The first gives the cement known as the Pouilly, and the intimate mixture of the two gives a cement with the composition of the Portland cement. An analysis of this cement gives the following result:

Lime	62.00
Silica	23.00
Alumina	8.50
Oxide of Iron	5.50
Water and carbonic acid	1.00
Sulphate of lime	traces.

M. Delesse gives the results of some recent analyses of Portland cement by Dr. Zuirek, of Berlin, as follows: three samples came from the principal works for the manufacture in England, and the fourth from the establishmeut cf the Brothers Menkow at Schwerin:

Analyses of four samples of Portland cement.

	Robins.		White Bros.		Knight, Bevans & Sturge.		Menkow.	
Silica	22.74		22.59		22.30		24.01	
Alumina	7.74		6.43		3.31		5.73	
Oxide of iron	3.70		4.03		9.75		2.39	
Lime	56.68	92.08	57 87	92.56	58.17	95.02	63.77	97.68
Magnesia	0 57		0.55		0.91		0.96	
Potash	0.46		0.74		0.41		0.49	
Soda	0.19		0.35		0.17		0.33	
Sulphate of lime	1.66		2.67		1.17		0.24	
Carbonate of lime	3.50		0.84		1.34		0.67	
Insoluble residue	0.50	7.59	0.77	6.51	1.06	5.02	0.93	2.11
Hygrometric moisture	1.90		2.23		1.47		0.27	

The Vicat cement is much more used in France now than formerly. It is manufactured on a large scale by Mr. Joseph Vicat, a graduate of the Ecole Polytechnique, and the son of the celebrated engineer. He forms a paste with clay and slaked lime in powder. This is made into loaves, which soon set and harden so that they are not injured by the weather, and do not require housing or artificial drying, as is the case when unburned materials are used. These loaves are then burned. This is substantially the process invented by his father. M. Delesse observes of the qualities of this cement, that it is homogeneous, the elements being in perfect combination; the clay is changed into silicate, which is completely decomposed without residue in a dilute acid. The setting is slow and does not commence for several hours after the mixing as mortar. The weight of this cement pulverized, but not compacted by ramming, varies from 1,300 to 1,400 kilogrammes to the cubic metre.

Some interesting applications of this cement were shown. It is used for making artificial breccias by mixing it with fragments of marble of various colors, moulding it into the desired form, and then by grinding and polishing the surface a beautiful mosaic is produced. Blocks so made may be sawed into slabs and polished like marble. They are hard and non-absorbent of moisture, and are said to be suitable for exterior decoration.

Among the hydraulic limes, that of Theil, Ardèche, continues to hold its high rank. The limestone beds from which it is obtained are highly fossiliferous, and are over 300 feet thick. Simple burning is all that is required to produce the cement. An establishment for its manufacture at Lafarge has 34 furnaces and produces 340 tons of sifted lime daily. The price is 15 francs per ton, and it weighs 700 kilogrammes per cubic metre. It is particularly valuable for marine constructions, and can be wetted with either fresh or salt water. It was used for the formation of the artificial blocks sunk to form the breakwater piers at Port Said.

The agglomerated béton of M. Coignet was most fully represented at the Exposition, and was used in the construction of the reservoirs and for the foundations of the outer gallery. For a full description of this material, its preparation and uses, reference is made to the special report by Mr. Leonard F. Beckwith. Reference may also be made to the publication by M. Coignet,* and by M. Claudel.†

OXYCHLORIDE OF MAGNESIUM CEMENT.

By mixing magnesia with oxychloride of magnesium a cement is formed analogous to that made with zinc oxide and the oxychloride of zinc. Both of these cements are the invention of Mr. Sorel. The hardness of the cement varies with the density of the chloride solution. An increased hardness is given by saturating the chloride of magnesium with chloride of barium or with sulphate of magnesia. The addition of 1 part of quicklime, or 2 parts of carbonate of magnesia, in 100 of the chloride at 25 deg. Baume, augments the hydraulic properties.

* Emploi des bétons agglomérés, etc., par François Coignet. Paris, 1862.
† Pratique de l'art de construire. Paris, 1863.

FERRUGINOUS CEMENT.

M. Alfred Chenot proposes to form a ferruginous cement by mixing iron in a state of extreme subdivision with sand. A cement so formed has long been known and used to a certain extent in the United States. M. Chenot proposes to manufacture the iron in a state of sponge and upon a large scale, by reducing iron ore, mixed with carbon, in a close furnace.

RANSOME ARTIFICIAL STONE.

This remarkable compound is adapted not only to interior, but to exterior construction, and rivals the natural sandstones in hardness and durability.

It is formed by mixing sand with soluble silicate of soda, and, when moulded into the desired form, treating the mass with a solution of chloride of calcium. A double decomposition takes place, hydrosilicate of lime is formed, and binds the grains of sand strongly together. For a full description of this artificial stone and its applications, reference is made to the report by Commissioner Barnard upon the Industrial Arts.

ZINC FOR CONSTRUCTION.

Zinc in its various forms of sheets, wire, nails, and stamped ornaments, appears to be much more used in construction in Europe than in the United States. The display by the Vieille-Montagne Company, and the Silesian Zinc Company of Breslau, was very extensive. Some of the advantages claimed for this material over other materials for roofing are its lightness, tenacity, and cheapness compared with lead, slates, or tiles. The Vieille-Montagne Company claim that the inclination of zinc roofs need not exceed 0m.1 per metre, while slate requires 0m.3, and tile 0m.45.

For a building 12m.50 long by 6m.80, covered with No. 14 zinc, at 80 francs the 100 kilogrammes, the cost would be :

	Francs.
With zinc, 1,075.09 francs, or per square metre	13.45
With slates, 1,245.97 francs, or per square metre	15.60
With tiles, 1,745.96 francs, or per square metre	21.80

For a shed 63m.00 long, 18m.00 wide, with an iron frame, and covered with No. 14 corrugated zinc, at 80 francs per 100 kilogrammes, the cost would be :

	Francs.
With zinc, 18,749 francs, or per square metre	16.50
With tiles, 22,767 francs, or per square metre	20.10

For temporary constructions they advertise sheets Nos. 10 and 11, which weigh 3k.45 to 4k.15 per square metre. It does not require painting, and the old sheets may be sold for 35 to 40 per cent. of the cost of new.

The Silesian Zinc Company manufacture zinc sheets of all sizes and thicknesses, from 2 ounces per square foot upward. The large plate exhibited is 17 ft. long by 54 ins. wide, and three-quarters of an inch thick. It could have been made twice as long as this, and with a total weight of 4,200 lbs., if room could have been procured for its installation. The corrugated sheets of large curve when laid lengthwise are made 9 ft. long and up to 40 ins. in breadth. These sheets are used chiefly for roofing large railway stations and other large buildings. The new Exchange at Berlin is covered with zinc from this establishment.

Some papers on the action of compressed air have recently come before the French Academy; and on the occasion of M. Delaunay remarking on bolides and aerolites, General Morin observed that artillerists found that in firing over a level near the ground, the dust was raised right and left by the compressed air acted upon by the ball. Ancient cannoneers, he said, spoke of valleys as attracting balls, because in such situations the compressed air afforded the greatest obstacle to their passage. In firing along a horizontal wall, and near it, balls deviated, so that if the wall was at the right, the balls went to the left, and *vice versa*.

We learn from "Cosmos" that in 1866 the 1,043 gold mines belonging to Russia, produced through the labors of 60,000 workmen, 26,560 kilos. of pure metal. Siberia alone possesses 500 auriferous sources, employing 34,000 persons. The Russian production of silver is less, for the various mines only produced 18,000 kilos. From the 7 platinum mines 1,712 kilos. were extracted. The Oural mountains and other places yielded 4,320 tons of excellent copper.

THE FESTINIOG RAILWAY.

Abstract from "The Engineer."

More than four years ago Captain Tyler, R. E., gave to the Institution of Civil Engineers a very complete and exceedingly interesting account of the little 2 ft. gauge, single line railway, extending from Portmadoc to Festiniog and Dinas, in Merionethshire. Precise and circumstantial as was this account, however, none who have not seen the line itself can possibly form an adequate notion of its extraordinary features. It may seem easy enough to imagine a 2 ft. gauge, or even easier to *see* it by laying down a couple of railway or other bars, or even a couple of light timber scantlings 2 ft. apart. But these bars or scantlings will not even then look like a practicable railway, and still less so if they have not their corresponding concomitants of liliputian earthworks —liliputian in respect of width, although not necessarily so in respect of depth or height. Look at them how you may, and in the light of a strong imagination, and they will appear but a pair of bars temporarily divorced from a common heap. You may compare them, if you have visited the cellars of the great London or Burton breweries, to the narrow lines of way along which casks of beer are rolled into dark distance, and into a highly carbono-acidulous and alcoholic atmosphere therein. You may compare them to the twin sides of an iron ladder, "barring" the rounds. Yet the 2 ft. railway gauge, or rather the 2 ft. 1 in. gauge, may be seen even in London, and for miles to the west, out of London. Within the 7 ft. gauge of the Great Western, a third rail has been laid down for the 4 ft. 8½ in. gauge, and, between Didcot and Wolverhampton, the inner rails of the 7 ft. gauge have been removed, leaving the old "six foot," as the intermediate space is termed, about 11 ft. wide, between the two 4 ft. 8½ in. gauges; the up and down lines, from their distance apart, appearing to belong rather to competing companies than to the same company, and seeming, indeed, to be in adjoining counties, or, at any rate, in separate "districts." But between Paddington and Didcot the inner rails of the 7 ft. gauge still remain, and between them and the inner rails of the 4 ft. 8½ in. gauge is a clear width of 2 ft. 1 in. If the traveller can imagine a real railway, of 1 in. less width, he may form some notion of the Festiniog line; not, however, as an entire railway, but in respect of its gauge alone. And would you, the passenger, consent to be whisked down to Didcot, at from 30 to 40 miles an hour, over that remanet from the 7 ft. gauge—that remanet of 2 in.—we mean 2 ft 1 in.—gauge? Look for a little time down that interminable perspective, and the 2 ft. 1 in. gauge converges to 18 in., to 12 in. to 6 in., to nothing at all. Even the 2 ft. gauge at your very feet seems, as you look again and again at it, to contract to 20 in., or even to 16 in. You cannot quite believe it to be even 2 ft., until you have measured it once more, and then you wonder why it was not laid down to a one-foot gauge, which, you almost believe, might have answered just as well. Indeed, you verge upon the late Mr. Holworthy Palmer's theory of no gauge at all—a single rail, from which, in his short railway near Posen, in Prussia, he suspended his carriages, but upon which, laid on the ground, you would suppose steam bicycles might be run, especially after Professor Rankine's more than wonderful recent algebraic analysis of how bicycles run at all. It may be—we cannot prophesy—that the velocipedestrian mania may result at last in working heavy trains over a single rail, and the Festiniog is certainly the nearest practicable approach yet made to this mode of working.

But it is not alone the narrowness of the gauge. There are curves as sharp as the sweep of Oxford Circus—at any rate of but 116 ft. radius for short lengths, while others are of 150 ft. to 264 ft. radius only. It is true they are parabolic curves, eased off from the straight line, and only gradually attaining and as gradually verging from their minimum radius. But over the extra-narrow gauge, and through these curves, almost sharp enough to be called corners, steam-drawn passenger trains are worked at a nominal regulation speed of 12 miles an hour, but at an actual speed sometimes exceeding 30 miles an hour, while the engineer of the line expresses himself equally ready, if the Board of Trade will sanction it, to run 40

miles an hour! And it is the fact that this line, having a total length of 14¼ miles, including branches, has been worked by locomotives for more than six years without a single accident other than what might have equally happened upon any gauge, viz., engines or wagons running off at points which had been set wrong. The successful working of the line is *un fait accompli*—a fact of 6 years' duration. So narrow and so crooked a line has no business to be worked at all; you seem to think it cannot be—never was—worked, but there is the fact. It *does* work, and, what is more, it pays. The traffic receipts of the little Festiniog line, from £30 to £40 per mile per week, exceed those of the North Staffordshire or of the Cornwall Railway, while they are very considerably above those of the Cambrian system of railways, and are greatly more than those of most of the Irish lines. And the whole cost, including a mile of breakwater in the Glaslyn estuary, half a mile of tunnelling, and an almost uninterrupted series of cutting in syenite rock, and breastwall embankments, or, rather rubble stone viaducts, together with stations, workshops, 7 locomotives, and more than 1,000 wagons and carriages, has been about £6,000 per mile. It is the pecuniary success of the Festiniog line, which pays about 30 per cent. upon its original capital of £36,000, which makes it doubly interesting. Upwards of £50,000 have been expended upon improvements, and this, taken from revenue, has since been capitalized, making a total capital amount of, say, £86,000, upon which about 12½ per cent. is now paid.

But it is not alone the gauge, nor the curves, nor the safe and profitable working of the line which make it interesting to the engineer. Nor is it even the grand scenery which it commands in the Mœntwrog Vale. Festiniog is 700 ft. above Portmadoc, the elevation being accomplished in less than 12 miles, giving an average gradient of 1 in 92, and a maximum gradient of 1 in 80. The line is cut into and embanked upon the steep right hand slope of this valley, furrowed as in this slope with the deep hollows of the mountain watercourses; and the cuttings, tunnels, and embankments are equally striking with the permanent way itself. The width between the nearly vertical sides of the cuttings is but about 8 ft., allowing hardly room for driving a cab through them; the two tunnels—one of 60 yards, and the other 730 yards—are scarcely larger in cross sectional area than the trains themselves; while the embankments, if we may give them that name—the engineer calls them "breastwalls"—are almost invariably stone walls 8 ft. wide at the top, with a batter of 1 in 6 on each side. Some of these breastwalls are 50 ft. or more in height, and are sharply curved. There are no parapets, and the passenger carriages almost overhang their edges, presenting a fine opening for destruction. An engineer from any railway of ordinary gauge, especially a double line, would look upon the work of the Festiniog Railway as but little more than a bridle path, resembling some of the narrow ways in the Alpine passes, or in the world-famed pathway from Laguayra to Caraccas in Venezuela. Indeed, the national duocorn of Wales, the Cambrian goat himself, would hardly find more than comfortable footing along the Festiniog line. Sheep stray upon the line, and we should ourselves have made Welsh mutton of a small flock of them, last Saturday, had they not considerately jumped in time down a steepish embankment.

As the two-feet gauge seems to grow narrower and narrower, the more you look at it, the most wonderful thing of all is that it should be worked by locomotives at all. Yet there are fine, although small engines, seven in all, designed and built by Mr. George England and Mr. R. F. Fairlie, who, alone, were prepared to carry out Mr. C. E. Spooner's (the engineer's and secretary's) requisition to work the line by steam power. We will not now repeat the names of some of the very first engineers of ten years ago, who, in Parliamentary committees, maintained that no useful, if indeed a safe, application of locomotive power could possibly be made on so narrow a gauge. It is enough to say that no locomotive builder, other than Mr. George England, could be found to guarantee any useful performance of locomotives upon such a line, and that, worked at from 160 lbs. to 200 lbs. steam, his engines have done very much more than he guaranteed they should do. These engines are, in themselves, great curiosities. The largest driving wheels among them are but 2 ft. 4 in. in diameter, while the prevailing size is 2 ft. These wheels

are worked, for the most part, by 8 in. cylinders, the pistons having 12 in. stroke, and with 160 lbs. to 200 lbs. steam in the little boilers, they can pull from 40 to 70 empty slate trucks, weighing 13 cwt. each, together with goods trucks and passenger carriages, up the 700 ft. rise in 12 miles, at the rate of as many miles an hour.

The Festiniog line affords an admirable proof of the advantage to be gained by resorting to a small gauge when the conditions of traffic permit; no one in his senses would, we fancy, abandon the wide gauge for the narrow under any other circumstances. Mr. Ramsbottom has laid down a line still narrower at Crewe. This little railway thoroughly answers the purpose for which it was intended. It is adapted to the demands made upon it, and it is therefore successful. In Norway Mr. Pihl has constructed two railways—one from Throndhjein to Storen, and the other between Hamar and Eleverum. The gauge is 3 ft. 6 in. The total cost of the Hamar line—24½ English miles long—was about £3,000 a mile. This includes an iron bridge 900 ft. long, 3 locomotives, 6 passenger carriages, 3 break-vans, and 50 goods wagons, with ballast wagons, and repairing shops and tools, 2 terminal stations, and 6 intermediate stations. The line rises 400 ft., and crosses many extensive and deep swamps. The Throndhjein line—31½ miles—cost £5,000 per line, including 4 engines, 8 passenger carriages, 3 break-vans, 60 goods wagons, and 20 ballast wagons, 2 terminal, and 6 intermediate stations, goods and carriage shades, and a repairing shop. For the following description of the line we are indebted to a statement made by Mr. Bruff, assistant engineer to Mr. Pihl, at the Institution of Civil Engineers in 1865:

"This line had to cross a ridge more than 500 ft. in height, in the first Norwegian mile from Throndhjein. The greater part of this distance was constructed on one side of the ridge, with gradients of 1 in 42 and 1 in 65, and on the other side of 1 in 52, the curvature being of about 900 ft. radius; whereas on the other portion of the line, where the gradients were seldom more than 1 in 100, curves of 750 ft. were frequently resorted to. The width at the formation level in cuttings and on embankments was 13 ft. nearly; the slopes, according to circumstances, were from 1½ to 1 to 3 to 1. The ballast was 8 ft. wide at the top, and 1 ft. 9 in. in thickness; the sleepers were of half round pine, 6 ft. 6 in. long, placed 2 ft. 6 in. apart on the curves and steep gradients and 2 ft. 9 in. on the straighter portions of the line. The rails were flat-bottomed and fished at the joints in the usual way, 3¼ in. in height, and weighing 37 lbs. per yard, except on the steep inclines, where rails of 41 lbs. per yard were laid. The rails were fastened to the sleepers by dog-spikes only, no bolts or bottom plates being used. Ransome's chilled crossings and Wild's self-acting switches were used throughout. The bridges were all of timber, except where large rivers had to be crossed, and spans of from 50 ft. to 100 ft. were required, in which case stone piers were carried up above flood level. The superstructure made use of in those cases was Howe's system of trellis work, w th iron suspending rods. For the other bridges and viaducts a simpler plan was generally adopted, and though of light and cheap construction, it had proved very satisfactory with regard to stiffness and solidity, even at heights of more than 90 ft. The rolling stock consisted of tank engines with 3 pairs of wheels, 2 pairs being coupled for drivers, these having an available weight for traction of from 11 to 12 tons, out of the 14 to 15 tons, the total weight. The last engines procured were provided with bogies, on Bissel's or Adams' system. The cylinders were 10 in. in diameter, with a length of stroke of 18 in., and the driving wheels were 3 ft. in diameter. All the engines were made in England, with the exception of 1 made at Throndhjein, and were working efficiently. The passenger carriages were constructed to carry the usual number of carriages as in England, and were arranged for 2 classes only, the compartments being fitted up as first and third. The goods wagons were made to carry 5 tons, and were only a few inches narrower than the ordinary kind, these widths being obtained by having the springs attached to brackets inside the sole bars, thereby allowing the lowering of the body, and, in consequence, the centre of gravity. The buffers were all central, and 2 ft. 6 in. above the rail level, and served also as drawbars. The couplings on those last constructed were self-acting when the wagons were brought together. As this narrow gauge allowed a correspondingly larger

wheel base than the ordinary gauge, the wagons ran very steadily. Some of the wagons were constructed to carry planks 24½ ft. long, and had a length of wheel base of 13 ft. The usual rate of speed was about 15 miles per hour, including stoppages, and the trains ran quite as steadily on this line as on the broader gauges. The traffic on these lines, though considerably below that of the lowest of the English lines, had already fully paid the working expenses, while the impulse given to the development of the resources of the country must undoubtedly, in course of time, produce a corresponding and satisfactory increase of revenue.

Simultaneously with the construction of the two narrow gauge lines, an extension—50 miles long—of the original trunk line, laid to 4 ft. 8½ in., was made to the Swedish frontier, the cost of which £6,400 per mile, the rate of wages and the class of work being as nearly as possible the same on all 3 lines. From this it appears that the broad gauge cost £1,400 per mile more than one, and £3,700 per mile more than the other narrow gauge line.

We have recently been placed in possession of some additional facts regarding the Norwegian lines, which we publish for the benefit of our readers. The following experiment was carried out long since to determine the tractive resistance on the 3 ft. 6 in. gauge. A train was made up consisting of a locomotive of the Bissel bogie type—11 in. cylinders, 18 in. stroke, 4 coupled drivers 3 ft. 9 in. diameter, total weight on drivers, 12.85 tons, of engine, 17 tons, and 16 plank trucks 26¼ ft. long each over all, 13 ft. wheel base; weight of each with load, 8¼ tons. This train was taken up a gradient 2½ miles long, of 1 in 118 in part, and 1 in 100 for the last mile at the top, with curves of 1,000 ft. and 980 ft. radius. The speed on the lower portion of the incline was 14 miles an hour; on the upper part, 10 miles an hour; boiler pressure, 100 lbs. to 120 lbs. The resistance per ton is about 11.75 lbs.

We have arranged in the following table particulars which explain themselves, and for which we are indebted to an English engineer, to whom they were supplied by Mr. Pihl:

List of prices, weight, carriage capacity, etc., of carriages and wagons on the 4 ft. 8½ in. gauge and the 3 ft. 6 in. gauge railways in Norway.

	Prices.	Length of body.	Width of Body.	Weight.		Carrying Capacity.		Weight of Carriage per one Passenger.
				Total.	Per foot run.	Total.	Per foot run.	
Composite first and second-class carriage, 4 ft. 8½ in	£328	20 ft.	7 ft. 3 in. to 8ft.	6.4 tons.	6.4 cwt.	32 pass.	1.6 cwt.	4.0 cwt.
Composite first and second-class carriage, 3 ft. 6 in	230	20 ft.	6 ft. 10 in.	5.45 "	5.45 "	32 "	1.6 "	3.4 "
Second-class carriage, 4 ft. 8½ in	240	20 ft.	7 ft. 3in. to 8ft.	6.02 "	6.02 "	28 "	1.4 "	4.3 "
" " " 3 ft. 6 in	131	20 ft.	6 ft. 10 in	3.80 "	3 80 "	28 "	1.4 "	2.7 "
								Carrying capacity per ton weight of wagon.
Lowsided goods wagon, 4 ft. 8½ in.	90	16 ft.	7 ft. 4 in	4.15 "	5.2 tons.	6 0 tons.	7.5 cwt.	1.45 cwt.
" " " 3 ft. 6 in.	64	16 ft.	6 ft. 6 in	3 3 "	4.1 "	6.0 "	7.5 "	1.82 "
Plank and timber wagon, 4 ft. 8½ in	90	18 ft.	7 ft. 6 in	4.4 "	4.9 "	6.0 "	6.7 "	1.36 "
" " " 3 ft. 6 in	62	18 ft.	6 ft. 6½ in	3.0 "	3.3 "	6 0 "	6.7 "	2.00 "
" " " 3 ft. 6 in	62	23ft. 6in.	6 ft. 8½ in	3.25 "	2.77 "	6.0 "	5.11 "	1.85 "

N. B.—When measured from outside to outside of buffers, 3 ft. is to be added to the length for the 3 ft. 6 in. gauge stock, and 3½ ft. for passenger carriages, and 2 ft. for goods wagons on the 4 ft. 8½ in. gauge stock.

THE French Government has sanctioned M. Duc's gift of 40,000 francs to the Academie des Beaux-Arts, for the purpose of founding a prize for the encouragement of architectural studies.

THE building of the new Roman Catholic church, at Arundel, England, has commenced. The height to top of spire will be 250 ft., and the cost will be £50,000.

IRON AND STEEL NOTES.

IMPORTS OF FOREIGN IRON AND STEEL AT NEW YORK.—For the week ending March 11, 1870.

	Quantity.	Value.
Railroad Iron, bars	2,099	$14,807
Hoop, tons	98	4,087
Sheet, tons	88	4,310
Pig, tons	290	4,685
Other Iron, tons	1,424	40,351
Chains and Anchors, packages	121	3,729
Tubes, packages	1,850	4,377
Nails, packages	7	447
Steel, packages	1,409	16,235
Machinery	37	3,973
Pipes	—	5,164
Anvils	30	246
Wire	855	5,990
Total value		$108,401

IMPORTS OF FOREIGN IRON AND STEEL AT BOSTON.—For the week ending March 11, 1870.

	Entered for consumption—Value.	Warehoused—Value.
FROM ENGLAND.		
Pig Iron	$6,775	....
Manufactured Iron	18,855	6,179
Scrap Iron	....	....
Wire Rods	....	....
Wire Rope	....	....
Iron Rails	....	....
Machinery	8,878	....
Nails	....	....
Chains	609	....
Steel Rails	....	....
Steel Tires	....	....
Steel	11,835	276
Steel Wire	....	....
Files	....	....
Pipes	....	....
Manufactures of Iron	505	....
Manufactures of Steel	630	....
Anchors	....	....
Anvils	....	....
FROM CHINA.		
Manufactured Iron	582	....
FROM BRITISH WEST INDIES.		
Scrap Iron	....	70
FROM HAYTI.		
Scrap Iron	50	....
FROM SWEDEN AND NORWAY.		
Manufactured Iron	32,958	....
Pig Iron	225	....
Total	$81,902	6,525

—Bulletin of Am. I. & S. Asso.

STEEL IN THE UNITED STATES.—The "Protectionist," speaking of the progress making in the manufacture of steel in the United States, says:

"Within the last six years it has been demonstrated that the steel-producing qualities do exist in American iron, and many of our best edge-tool manufacturers and machinists testify that steel, both cast and rolled, made in Pittsburg from American iron, is fully equal to the best English makes.

"The steel-producing capacity of the works in and around Pittsburg alone, is estimated at 75 tons per day. This industry may, therefore, be deemed an accomplished fact, and brief as its history is, it has already exercised an important influence in controlling foreign prices."

It is shown that American axes, shovels, spades, hoes, etc., have entirely taken the place of foreign tools. Nothing equal to them in shape or finish is made abroad, and they are now largely exported. American butts and hinges of all kinds are cheaper and better, and entirely excludes all foreign goods. In cutlery of all kinds, the medium American qualities, of which the largest bulk enter into consumption, are cheaper and better than those of foreign importation; only the very low and worthless grades, or the very expensive and luxurious styles, can now be imported.

HOMOGENEOUS IRON RAILS.—Chief Engineer Stockton, of the Allegheny Valley Railroad, in his annual report, makes the following comparison between iron and steel rails:

"In regard to the durability of iron rails I have never seen a rail perfectly homogeneous worn out; neither have I ever heard any civil engineer say that he had, and I have frequently asked the question. In speaking of these things to a prominent iron manufacturer of this city, he kindly proposed to furnish to this company a couple of iron rails made from his common merchant bar. These were received and laid on the track in March, 1868, and on the opposite side of the track were laid steel head-rails, manufactured in Michigan. Both were laid at a point where it was supposed they would receive the roughest service. In less than six months some of the steel rails had given out, and shortly after they were lifted and Brady's Bend rails supplied. These were worn out and others supplied and worn out, while the two rails furnished by the party above referred to, remain in the track apparently little the worse for the service."

RAILROAD IRON.—A correspondent writes as follows to the Boston "Commercial Bulletin:"

We know that Great Britain now consumes and markets 5,000,000 tons of iron annually, whereas for the last 30 years she manufactured 16,000,000 tons, 9,000,000 of which was railroad iron, and that up to date she had not produced 16,000,000 tons.

The cost of iron is based on these facts: it requires 38 to 46 cwt. of ore, 30 to 50 cwt. of fuel, 12 to 18 cwt. of flux, with 13 tons of air blown in, with all the labor to produce the same, to make 1 ton of iron. Mr. Trueman, C. E., author of "British Iron Manufactures," says of cast iron: "The property of the greatest importance is tenacity, and is a quality of the first, if not of paramount importance. Transverse strength next, and is directly dependent on the tenacity of the metal, also power to resist impact, do. fatigue, do., crushing forces, hardness and texture."

Look at our development from decade to decade, prior to the introduction of the steam-engine, and from that to the introduction of railroads, and from that to this date, and you will see that since the introduction of railroads we have increased twofold in population, and fourfold in productions in per cent. over former decades. And our country is not one-half developed east of the Mississippi river, by railroads, compared with the most prosperous States.

Our railroads in 1850 owned 8,539 miles, and

to-day own 52,500 miles; we then possessed one through route, viz., the New York Central, and that had to pay canal tolls for the privilege of carrying freight, which amounted for many years to a prohibition, and to-day we have, say, 12 through lines. And if the roads carry one-quarter of the tonnage that the New York and New England roads do per mile, which is 850 tons, they carry 44,625,000, which, at $1.50 per ton, is $66,937,500; and if they should carry equal to the Boston and Maine Railroad, it would amount to over six hundred billion of dollars, and in 1900 A. D. will amount to threefold that amount.

These roads have been created chiefly by men who were not practical, and were, therefore, built at a great cost, as building and equipping railroads was a new business. The rails were made chiefly from inferior iron, known as the American brand, which has sacrificed much life and property, and in many cases, the roads themselves. State taxes were levied by New Jersey, Maryland, Pennsylvania, and other States, on passengers and tonnage. In the face of these obstacles we have attained our present wonderful development.

Manufactured in 1868.	Tons.	Value.
Foundry iron	575,000	$22,425,000
Hammered do	22,000	3,960,000
Boiler plate	111,462	15,047,370
Railroad iron	506,714	34,384,148
Bar, rod, hoop, axle and other rolled iron	337,828	35,048,850
Total	1,553,004	110,860,368
Bessemer steel	8,500	850,000
Cast and puddled steel	21,500	4,300,000
Total	30,000	5,150,000
Nails and spikes	149,000	16,390,000
Imported in 1868.		
Steel, ingots, bars sheet wire		1,705,337
Manufactured iron and steel		8,728,955
Railroad iron	228,277	4,781,575
Total	228,277	15,205,867
Domestic manufactured	1,553,004	110,865,368
Total	1,781,281	126,081,251
Domestic manufactured Bessemer cast and puddled steel	30,000	5,150,000
Total	1,811,281	131,231,251
Domestic manufactured nails and spikes	149,000	16,390,000
Total	1,960,281	$147,621,251

If iron has done so much for us as a nation, and must continue to do for us, at the rate of $600,000,000, in 1900 A. D., have we done our duty to it? Certainly not; for we are making our iron much inferior to that made before this great development, and make it from the best ore in the world. We are growing poorer yearly, even if the quality of our iron remain the same, as we exact greater burdens from it than it can bear, caused by the development of the country over a larger area, which demands higher rates of speed and heavier and longer trains of all our railroads.

We now know that we have laid in the 52,500 miles of railroads 4,725,000 tons, which every 10 years must be re-rolled, based on English railroads (but when based on some of the best railroads in the United States, every 4 years, based on 5 years' experience), which (472,500 tons annually, at $75 per ton), is $35,000,000, and that this 10 per cent. is worn and

By oxidation lost	$3,500,000
And a further cost in car wheels of	1,250,000
And will lose to re-roll some $25 per ton	11,812,125
Annual loss to the railroads	$16,562,125

This loss in car wheels is based on their lasting 5 years, instead 2-31, as they do on New York roads, viz., passenger, 1-58, freight, 3-04, and they carry a weight per wheel: passenger, 3½ tons; freight, 1.47 tons, and allow one-half for old wheels. In 1900 A. D. the annual loss will be threefold—$16,562,125—based on population, and will double that based on production of other articles of iron, making a total loss of wear of iron to the nation of between $100,000,000 and $200,000,000 annually. And this loss is made when we own the best ore in the world, caused by several reasons, chiefly by the purchasers demanding a cheap iron, not knowing the value of iron, excepting as based on price, and the competition of the manufacturers against each other.

Of 17 cannons which were made for the United States from hot blast charcoal iron, 8 failed to stand the test. Cast-iron increases in strength from 403 lbs. on the first melting, to 725 lbs. on the 12th melting; bars 1 in. by 4 ft., and of cold blast charcoal pig-iron.

Mr. Mallet says of forgings 24 to 36 in. in diameter, "that they are liable to one or more rents, and have been found 18 ins. long, ¾ wide in the centre, caused by contraction after leaving the hammer. Again, the iron decreases in strength from the long exposure to the intense heat necessary, without the possibility of restoring the fibre by hammering. Again, hammer hardening, especially cold hammering, produced by making finished work or to give the form demanded to save cost of turning or planing, will produce crystallization and impair the iron.

We find the	Density.	Tenacity.	Comp. Strength. per sq. in.
Cast iron, least	6.900	9.000	84.529
" greatest	7.400	47.000	174.120
Wrought iron, least	7.704	38.027	40.000
" " greatest	7.858	74.592	127.720
Steel, least	7.029	60.000	198.000
" greatest	7.862	128.000	391.905
Baur or chrome steel, greatest		186.000	

Baur or chrome steel is not only one-third stronger than any other steel, but can be produced at small cost, from the fact that when worn out, as in a steel headed rail, it has a market value, as it can be made over again, which is not the case with Bessemer or any other cast steel. It will also weld without borax or flux, and when burnt can be redeemed on the next heat.

Seeing such facts, must not abandon iron for many purposes, by converting it into Baur steel, to enable us to develop the resources of our country at a low cost, for the cheaper we can do it, the more we can develop it, and through railroads we must do it. The 52,500 miles of roads cost $350,-

000,000. If they were all steel rails they would cost $600,000,000; this great expense of $250,000,000 the roads would not bear even if it were practicable, which it is not, on account of the extreme winters; therefore we want a rail with the toughness of iron and the hardness of steel, which can be produced in a steel headed rail.

The present cost of re-rolling the 10 per cent. of nails annually re-rolled, with the loss from wear and oxidation, is	$15,312,125
Cost to make these rails steel-headed, carrying 1.5 Baur steel, 472,500 tons, and $25 extra	$11,837,500

Which would wear as long as six iron rails.

This estimate of value does not include the extra expense of setting the rails in either case, which will give a still greater saving in favor of the steel-headed rail. From these combined facts we think the consumption of steel must increase.

We shall make 10 per cent. of all the railroad rails and car wheels	$16,562,125
Reduce the importation of rails $\frac{1}{3}$	2,390,787
Reduce the importation of steel $\frac{1}{4}$	852,669
Reduce the importation of articles made of steel and iron $\frac{1}{2}$	4,369,476
Also use cast steel for all large castings and forging, as the increased development of our country increases the drawing burden, and that increases the wear of the rolling stock of railroads, engines, steamers, etc., and said weight can be reduced full one-third, and diameter of bearings one-half, which will reduce the friction, and we can therefore depend upon one-tenth of our castings and forging being of steel. (The steamship companies will endorse this, as many lines lose 1 or more shafts annually.)	7,648,122
	$31,823,180
And in A. D. 1900, must be about	100,000,000
Instead of, as in 1868	5,150,000

RAILWAY NOTES.

A NEW RAILWAY CONNECTION BETWEEN THE EAST AND THE WEST.—It is well known that the deficiency of railway connection outward from Chicago causes, at certain seasons of the year, a blockade of transit across the State of Michigan. There are, in fact, but two trunk lines, with some auxiliary connections that do not add much to their efficiency, to bring eastward from Chicago, the vast product of the North-west designed for the New York market. When we say the New York market we mean its demand for export as well as for consumption. The two existing trunks are the Michigan Central and the Michigan Southern, both of which are overladen with freight and travel every day in the year, and do not answer the actual requirement demanded by the North-west. In fact, the usual order of things is reversed on this latitude of transport. Instead of the railways seeking freight, and drumming for it, a vast surplus of freight is all the time drumming for passage. In this state of things, it is gratifying to announce that a new main trunk line is now in process of construction. the capacity of which will be equal to that of either the Michigan Central or Southern. Beginning at the joint terminus of the Grand Trunk and Great Western lines of Canada, it goes westward to Flint, and thence south-west to South Bend, a distance in all of 220 miles, of which the grading, bridging and road bed are finished, and some 65 or 70 miles, that is nearly one-third of the way, is actually completed and running. The remaining portion, from South Bend to Chicago, will be prosecuted with vigor. There is not a more needed work in progress, nor one that promises to pay a better profit. The line, composed of several sections, is known by the name of The Port Huron and Chicago Railway Line.—*Iron Age.*

ILLINOIS CENTRAL RAILWAY LOCOMOTIVE REPORT FOR DECEMBER, 1869.

DECEMBER, 1869.	Chic. Div.	South Div.	North Div.	Iowa Div.	Total.
Miles of road	252.5	230.75	225.0	231.0	939.25
MILES RUN:					
By passenger trains	34,832	34,101	26,673	13,753	109,424
By freight trains	107,515	63,197	111,434	45,753	327,902
By other trains	29,586	11,309	11,662	5,650	58,127
Total miles run	171,485	109,467	149,764	65,167	445,883
RUNNING EXPENSES:					
Pounds of waste used	2,426	1,645	2,117	867	7,049
Gallons of oil used	1,660	1,029	1,423	582	4,686
Cords of wood used	267	57	81	46	450
Tons of coal used	5,191	3,118	4,919	1,976	15,295
Cost of wages	$10,441	$6,304	$8,999	$3,600	$29,244
Cost of repairs	24,273	11,876	13,771	3,938	53,459
Cost of fuel	14,886	8,193	12,865	5,260	41,165
Cost of cleaning engines	2,326	1,260	1,167	699	5,453
Total cost	53,846	28,499	36,874	13,977	133,196
COST PER MILE RUN:					
For oil, waste and tallow, cts	0.79	.79	.78	.73	.77
For repairs, cts	14.50	10.85	8.53	6.64	10.78
For fuel, cts	8.65	7.48	8.59	8.07	8.39
For wages, cts	6.08	5.76	5.94	5.52	5.89
For cleaning, cts	1.35	1.15	0.78	1.07	1 10
Total, cts	31.40	26.03	24.62	21.44	26.84
AVERAGE MILES RUN.					
To one cord of wood	.....	.....	.....	.....	.....
To one ton of coal	33.01	31.89	30.45	32 25	32.25
To one pint of oil	12.41	13.41	13.15	14.00	13.23
Average number of cars per train	15.20	11.56	13.26	12.31	13.03

The above oil includes that used in head-lights and in lamps of engineers; wood is rated at $7.00 per cord, and coal at $2.50 per ton, loaded on tenders; oil 60 cents per gallon; waste 15 cents. per pound. Re-building, superintending, teaming, and all other expenditures relating to repairs, are included in the above cost of the performance of locomotives. Two empty cars are rated as one loaded. Whole number of engines owned by the company, 177. Average cost per mile, in cents, for

Passenger engines	20.74
Freight "	29.05
Construction "	24.20
Switching "	17.73

SAMUEL J. HAYES, Superintendent of Machinery. —*American Railway Times.*

AMERICAN RAILROADS.—The growth of the railroad system in this country is shown by the following table:

Year.	No. Miles.	Increase.
1835	1,098	....
1836	1,273	175
1837	1,497	224
1838	1,913	416
1839	2,302	389
1840	2,818	516
1841	3,535	717
1842	4,026	491
1843	4,185	159
1844	4,377	192
1845	4,633	256
1846	4,930	297
1847	5,599	669
1848	5,996	397
1849	7,365	1,369
1850	9,021	1,656
1851	10,982	1,961
1852	12,908	1,926
1853	15,360	2,452
1854	16,720	1,360
1855	18,374	1,654
1856	22,017	3,643
1857	24,508	2,491
1858	26,968	2,460
1859	28,789	1,821
1860	30,635	1,846
1861	31,256	621
1862	32,120	864
1863	33,170	1,050
1864	33,908	738
1865	35,085	1,177
1866	36,827	1,742
1867	39,276	2,449
1868	42,255	2,979
1869 (estimated).	50,000	7,745

It thus appears that the number of miles of railroad constructed in this country during the year which has just closed is equal to all that existed up to 1849, and exceeds the total construction of any two former years. On this exhibit the "New York Tribune" remarks as follows:

"The 7,745 miles built in 1869 must have cost at least $300,000,000 (which would not be quite $40,000 per mile; and the cost of our railroads and their equipment averages more than that sum). Is it a wonder that we fall in debt to Europe?

"Of course we need railroads, and must build them. We shall probably have 100,000 miles in operation before the close of this century. But we cannot build all we need next year; and there must be a pull-up, or another 1837 will be down upon us. Gentlemen who are intent on more railroads! be good enough not to start any till after 1870, and let us try to fund our national debt!"

Under wise legislation which would equalize our foreign trade and expand our currency only as business expands, the country could extend her railroad system as rapidly as she requires it without running much into debt abroad. But it would have to be accomplished under different legislation from what the "Tribune" recommends.—*The Miner's Journal and Coal Statistical Register.*

THE GREAT LUXEMBOURG RAILWAY.—SIR,—I have had my attention called to your report of the meeting of this company, in which the chairman, Mr. W. Fenton, is stated to have said, in answer to the inquiry of an honorable shareholder respecting the "Fairlie engines," that he had asked, and I had refused to build an engine on their terms, but that I had made a counter-proposition which they could not accept, as they "would not be justified in making any experiments at the cost of the company." Will you kindly permit me a little space to state the facts?

Mr. Fenton asked me to supply an engine, and place it on his line in Belgium free of cost to the company, and that if the engine "should prove to be a success," of which he was to be the judge, I should be paid for it. I replied, situated as I then was, having already spent a fortune in illustrating and proving the value of the principle, I could not afford to accept the terms of the proposition as put; but I suggested that the company should advance me the money to build and deliver an engine on their line, and that if it did not do the stipulated duty I would undertake to remove it, and return every shilling advanced to me. I further stated that although I had not ready money sufficient to build an engine at my own cost, yet in the event of failure I would be prepared to guarantee the return of the money. I am willing to carry out this proposition, and will undertake to place engines on the Great Luxembourg Railway that shall enable that line to carry nearly double its present traffic, at a very large reduction in the cost of haulage per ton; thus permitting a considerable reduction in its tariff, whilst at the same time the engines should not damage themselves or "murder the rails" to anything like the extent that is now done with the ordinary engines. I know that the attention of the locomotive superintendent of the Great Luxembourg Railway was pointedly called a short time ago to my system, by a gentleman who thoroughly believed in it, and for whom he had been asked to design certain engines; nevertheless, he put aside that gentleman's recommendation, and designed the engines on a plan wholly different from mine. Such a fact will indicate the opposition my engine would encounter on the Great Luxembourg Railway, yet I am willing to face all this and take my chance. I am Sir, your obedient servant,

ROBERT F. FAIRLIE.

9, Victoria Chambers, Westminster, March 16.
—*Railway News.*

NEW COUPLING FOR RAILWAY WAGONS.—There is no feature in railway history more distressing than the dangers to which a humble but most useful class of servants are exposed in goods station duty, and numerous plans have been invented to obviate the necessity of men passing in between the wagons in shunting. It is perhaps true that many men get hurt by their own carelessness, and the accidents may be individually small. But they make up a large total of suffering and loss, and there is, we are sure, no manager or board that would not gladly adopt any reasonable means to prevent them. We have had an opportunity of inspecting a coupling invented by Mr. James Mackenzie, a gentleman in the service of the North British Company, which appears well suited to attain the end in view, and at moderate expense. The latter is, indeed, the main consideration, for the accidents cost money, and if a plan could be introduced which would cost less for interest on the expenditure necessary for its adoption, we think it would be received with general favor. Mr.

Mackenzie's plan, which has been tried practically in presence of his board of directors, possesses four excellent qualifications. It is—(1) simple in character; (2) requires no alteration in the present style of hook-and-chain coupling; (3) it can be used on any wagon, whether the one next it has the same fitting or not; and (4) its use is not affected by different height in the wagons or different length of buffers. It possesses the further merit of cheapness, the cost per wagon to fit both ends being estimated at 15s., and the inventor states it can be applied to any existing wagon in a quarter of an hour. As a matter of course, the system would save *time*, as the coupling or uncoupling can be done much more rapidly than by the present mode. The invention consists in the first place of two parallel rods, hanging from the wagon at the sides of the coupling-hook. A transverse rod works in rings which form the end of the two first rods. From this cross rod two projectors run parallel with the lowest link of the coupling chain, and grasp the link by two sliding catches. The cross rod is produced beyond the sides of the wagon, and is bent at each end into an angle, like the letter L. The action of the rods is exactly similar to that of the human arm, the first pair of rods representing the shoulder-joint, and the play of the cross rod giving the elbow action. Grasping the rod at the side of the wagon by the heel and the point, the porter first raises the coupling-chain by raising the rod, and then by pressing on the lever furnished by the projecting limb, the lower link of the coupling-chain is moved with an action exactly like that of the elbow-joint. Without a diagram it is not easy to convey an adequate idea of the extreme simplicity of the invention, but having seen it in operation, we can state that its action is exceedingly natural, and is likely in practice to prove satisfactory. Mr. Mackenzie's invention is to be submitted to the Royal Society of Arts at Edinburgh on Monday evening, when the inventor will personally describe it, and exhibit a working model.

ORDNANCE AND NAVAL NOTES.

IRONCLADS, PRESENT AND FUTURE.—A lecture on this interesting and important subject was delivered last Monday evening at the Royal United Service Institution, by Mr. Charles F. Henwood, who possesses, as is well known, a large experience in designing and building iron armored plated ships. Mr. Henwood showed that the 47 ironclads which comprise our entire navy, and which have been divided into thirteen classes by the present Admiralty, are so various in their speeds, their sail-power, their handiness, and offensive and defensive power, that they are incapable of being combined for maximum uniform operations. This is clearly shown by the fact of there being 13 classes in 47 vessels. The importance of uniformity cannot be overestimated. Sir William Fairbairn has stated that "it is essential that the steam navy of this country should have great command of power, to enable the ships to manœuvre at sea with the precision of a squadron on parade." And Captain Selwyn says, "If you do not give us the highest speed attainable by any man-of-war afloat in the world you take from the navy the power of catching that man-of-war—and practically, whether your ship costs £1,000 or £1,000,000, if they cannot do the work they are sent out to do, the money had better not have been spent." The defects of the Audacious class, of which 6 are building, before one has been tried, were severely criticised; and it was shown that, although the Hercules is very strong at about the water-line, the armor protection of the fighting part of the ship was very inferior, being only plated with 5 in. in thickness. The defensive powers of the Monarch were incapable of resisting shot from similar guns to her own; in this respect the Captain was but slightly superior, but on the whole more completely defended than either Hercules or Monarch. The Captain, although only designed to compete with the Bellerophon, compares vrey favorably with those vessels as follows:

	Hercules.	Monarch.	Captain.
Length	325 ft.	330 ft.	320 ft.
Breadth	59 ft.	57¾ ft.	53¾ ft.
Displacement	8530 tons.	8164 tons.	7650 tons.
H. P. (nominal)	1200	1100	900
Speed, in knots	14.69	14.9	14.32
Number and calibre of guns	8 400-pr. 2 250-pr. 2 115-pr.	4 600-pr. 2 115-pr.	4 600-pr. 2 115-pr.
Weight of broadside	280 lbs.	2515 lbs.	2515 lbs.
Tonnage	5234	5102	4272

Taking the cost per ton, and per horse-power to be the same in all three cases, the Captain will have cost £62,800 less than the Monarch, and £77,220 less than the Hercules. The Captain, therefore, takes her place at the head of all our sea-going ironclads as being the most powerful, and at the same time most economical; and it is to a private shipbuilding firm in conjunction with Captain Coles, that the country is indebted for this highly satisfactory result; it is true we have yet to learn their comparative sea-going qualities, but there is no reason to doubt that the Captain will not, at least, equal either the Hercules or Monarch. The Devastation and Thunderer, turret ships, without masts and sails, are only estimated to have a speed of 12½ knots. This was a very serious defect in the days of high average speeds obtained by our Transatlantic steamships, and the high economical speed of our earliest ironclads. Moreover, the Admiralty had practically condemned these vessels, even before the second has been laid down, by proposing to build the third of this novel class of vessel of larger dimensions, horse-power, and higher speed. These three purely experimental vessels will cost the country about £1,000,000 sterling, whereas, in another and simpler way, we might obtain practically as efficient vessels for about one-third the money, by converting the best of our screw line-of-battle ships in the manner described in "The Engineer," February 4th, 1870. Considering that, in a few years, more powerful guns will be produced (for the Russian Government already possess 50-ton guns, firing shots 1120 lbs. weight with 130 lbs. charge of powder, one of which has been fired over 300 times), and that the zincking of ship's bottoms, and liquid fuel for generating steam, are still unsolved problems, which may involve another reconstruction of our navy, it would be a wise economy to adopt Mr. Henwood's proposal, for thereby, not only should we obtain practically as good vessels at one third the cost, but a portion of the money thus saved might,

with advantage to the country, be expended in making judicious and exhaustive experiments for solving these questions; and so should we obtain real economy with efficiency and advance in the true path of progress.—*The Engineer.*

THE HOTSPUR.—On Saturday afternoon there was launched from the Govan shipbuilding-yard of Messrs. Robert Napier & Son, Glasgow, a screw armor-clad ram, built for the British Government, and named the Hotspur. The dimensions are as follows: Length between the perpendiculars, 235 ft.; breadth, 50 ft.; depth in hold, 20 ft. 1 in.; burden, 2,637 18-94 tons, builder's measurement; and 600-horse power. This war-ship is constructed on a principle that is entirely new in this country, but which was adopted some time ago in connection with the navy of France. Its chief features are the formation of a fixed tower or turret, the breastwork of which is 8 in. thick, and an immense ram forward. The diameter of the turret, which is pear-shaped, is 31 ft. 6 in., and 35 ft. 9 in. from the aft to the fore side. This stationary turret is armed with a 30-ton gun, carrying 600 lbs. of shot. It is worked on a revolving turn-table, the diameter of which is 26 ft.; from the two front portholes the gun has a training of 69 deg., and at the side portholes a training of 4½ deg. aft, and 26 deg. forward, so that it is able to fire right forward, and almost, but not quite, right aft. The gun can be elevated 12½ deg. and depressed 7, the recoil being 6 ft. 3 in. The ram projects about 9 ft. below water, and is brought up to a sharp point at a depth of about 8 ft. below the water-line. There are three decks, the middle one being plated with two thicknesses of iron tapered forward and aft. The engines, which have been made and fitted by the Messrs. Napier, are of the direct-acting horizontal description, having two piston-rods to each cylinder, and are fitted with surface-condensers and all the most recent improvements. The boilers, of which there are four, are of the ordinary tubular type, with five furnaces each. The propellers are 14 ft. in diameter, on Griffiths' plan, with movable blades. In all, six armor-clads have been built by the Messrs. Napier for the British Navy. In 1856 they set afloat the Erebus, in 1861 the Black Prince, in 1862 the Hector, in 1869 the Audacious and Invincible, and now the Hotspur.—*Mechanic's Magazine.*

LIFESHIP.—Capt. Hans Busk exhibited at the *conversazione* of the Royal Society on the 5th inst. a model of a steam lifeship, which he offers as likely to render good service where the lifeboat fails. The lifeship with a crew of thirty men is to keep the sea, and in case of falling in with a vessel in distress, would render assistance from the windward, which would be easier, and often more effectual, than when borne from the leeward in the teeth of a gale by a lifeboat. The lifeship could "warp down" a boat to a helpless vessel, or, approaching near and dropping anchor, could fire a rocket and send a line with the wind, and so establish communication.

THE INVINCIBLE.—The new double-screw iron ship, iron-plated, Invincible, 14,? recently brought from Glasgow to Plymouth, made a preliminary trial of her machinery on Saturday, when she ran from Penlee Point to the Eddystone and back with a satisfactory result.

ENGINEERING STRUCTURES.

THE BULGING OF WALLS—CAUSE AND PREVENTION.—The ugly protruding curvature commonly called a bulge, to which external and front walls seem especially subject, may frequently be traced to original defects of construction. Bulges may often occur at about the level of a floor, and where there is a floor, the brick-work of outer walls is commonly weakest. To avoid running the floor-timbers into party wall, they are generally made to rest on the front and back, and the party wall will often appear in better condition than the front. Immediately below the level of the intended floor, a timber scantling about 4½ in. by 3 in. is laid along the wall flush with its inner face, to receive the ends of the joists. The joists, let it be assumed, are about 10 in. deep, notched to 9 in. at the ends, so as to rise the height of three courses of brick wall. Here, then, bond-timber and joists together make a height of 12 in., or four courses of brick-work. The joists will have a bearing of 6 in. on the wall, and the wall may be supposed to be a brick and a half thick. Now, wherever the joists occur, there is a complete interruption of the bond on the inner side of the work, while externally it appears unbroken, the outer face, in fact, being carried up half a brick in thickness, and looking as though the whole wall were perfectly solid and uniform; but the backing between the timbers too often consists of bats and small pieces put together in a mysterious though incongruous way. So long as the timber remains sound and of its full dimensions, all is well, but this is seldom very long. The manner of converting balk-timber in scantlings precludes the permanent retention of its original form. When felled and squared in its native forests, it is thrown into the first lake or river, formed into rafts, and navigated into some port of shipment, where it is formed into cargoes for conveyance across the ocean. The sea voyage over, it may be assumed to the port of London, the timber is again immersed in water, which usually constitutes its only place of storage till wanted for actual application to some building. As to deals, an architect may specify dryness as a necessary quality, but he must not expect it in timber. He may say that it shall be sound and well seasoned, but water-seasoning is all that takes place previous to conversion, and this fact is noteworthy, because as the subsequent shrinkage may be estimated at three-quarters of an inch in the foot, it becomes obvious that so far as the bond-timber and joists are to be regarded as forming the inner material of the wall, a subsidence equal to the shrinkage must take place. But the wall does not depend on the wood-work alone, and the irregular filling up between the joists will receive the weight, and so evil will be deferred. For the time there may be no other visible result than the dropping of the floor from the skirting, and when the latter is of wood, the simultaneous rising of the skirting from the floor. It is when the wooden bond, having shrunk to the minimum dimension of perfect dryness, enters upon its course of decay, that the worst consequences of inserting timber constructionally in walls are developed. The inner face then sinks, and the statical conditions are disturbed, and bulging is inevitable.

It was the custom of bygone days to insert timber very freely in walls. Foundations were fortified, as it was thought, by the introduction of a

"chain-bond" of large scantling, and many a goodly edifice has suffered from the practice. Great, therefore, have been the improvements adopted in the modern construction of walls. A solid basis is formed by the use of concrete; wrought iron hooping has advantageously displaced wooden bond, and the joists are kept as much as possible out of the walls, their ends being supported by brick or iron corbels. Thus all rapidly perishable matters are excluded, and a lasting character imparted to work so executed. Skirtings also are made of stucco instead of wood, and shrinkage in that quarter got rid of. Thus experience and science are gradually removing one of the old defects and disfigurements of buildings—the bulging of walls.—*Building News.*

THE BRIDGE TO CONNECT PHILADELPHIA WITH CAMDEN.—It is stated that the stock of the Philadelphia and Camden Bridge Company has all been taken, that the plan of the structure has been adopted, and that the work will shortly be undertaken and pushed forward with all convenient speed. The construction of great bridges is the prominent feature of engineering work at the present time. At St. Louis and at Brooklyn immense caissons of iron have been made for foundations in piers at a great depth, and something of the same kind will be needed for the great viaduct across the Delaware. One of the admirable features of this work will be the arrangement of the draw, by which ships may be passed without any serious impediment to travel on the bridge. The track will be divided at this part of the bridge, so that one part may be open for the passage of a vessel, while cars and vehicles are crossing on the other, and the first part closed when the second is opened. Steamers and small sail-vessels will pass under the span of the bridge which will be over the main channel, at such a height as to form no obstacle to their movements.

The completion of this work will wonderfully stimulate improvement in Camden and its vicinity. The business portion of Philadelphia is near the Delaware, and this bridge will practically bring Camden nearer to it than the outer parts of the consolidated city now are. Passenger railways, using dummy engines, will radiate from the eastern end of the bridge, and the country within a radius of ten miles will be but half an hour's ride from Market and Second streets in Philadelphia. The increase in the value of real estate in a few years will pay the cost of the bridge three times over.—*Philadelphia Underwriter.*

NEW BOOKS.

A HAND-BOOK OF PRACTICAL TELEGRAPHY. By R. S. CULLEY. Fourth edition, revised and enlarged. Published by D. Van Nostrand.

The first appearance of Mr. Culley's "Handbook of Practical Telegraphy," in 1863, inaugurated a new era in telegraphic literature. Although of small size, and written in a simple and unpretending style, it contained more common sense and more practical information than all the previous works which had appeared in the English language combined. Although not faultless, in a scientific point of view, yet it was so far in advance of all its predecessors, and supplied such an obvious and long felt desideratum, that it was gratefully received by a large class of eager students of electrical science, who, for the first time, were enabled to avail themselves of that technical knowledge of the laws of electricity, and its practical application, before attainable only through verbal instruction, or the tedious school of actual experience. Since that time the labors in this field have been enlarged and extended by the publication of such works as those of Clark, Sabine, and Pope, which, though differing widely from each other in their mode of treatment of the subject, are all characterized by the distinctively practical character of which Mr. Culley in his work was the first to set the example. During this time, however, the author of the "Hand-book" has not been idle, but has kept pace in successive editions, with the rapid development of electrical science, which has been such a marked characteristic of the past decade.

The fourth edition, which now lies before us, is nearly double the size of the original work, and in addition to the new matter which has been incorporated with it, the older portion has been revised and re-written. The volume, as a whole, is a credit both to the author and the publisher.

The first part of the work treats of "Sources of Electricity." A lucid and correct explanation is given of the theory of the action of batteries, supplemented with descriptions of the different kinds, and useful directions for their maintenance and management. In the introduction it is stated that the Daniell battery is used by the three great telegraph companies of England, now merged into one system and under government control. The form most generally employed is an oblong box or trough, divided into five cells, with flat plates of zinc and copper, about four inches square, instead of placing each couple in a separate cylindrical tumbler, as is usually done in this country. The English arrangement is convenient, cheap, and economical of space.

The Leclauche battery, recently introduced, is described, and appears to give good satisfaction. the electro-motive force is equal to 1.6 that of Daniell, with much less internal resistance; but when placed in short circuit it polarizes very quickly, and it, therefore, cannot be used for permanent currents nor as a local battery. Mr. Culley says that the Marie Davy, or sulphate of mercury battery, is almost exclusively employed at the Central office of the French Administration of Telegraphs in Paris.

Mr. Culley devotes a chapter to the important subject of insulation, in which this matter is more fully treated of than is usual in works of this class. In describing the qualities desirable in an insulator for telegraph lines, he says: "The best insulator is that which has the smallest possible diameter consonant with strength, with the greatest distance between the wire and the bolt or support, and which can be maintained in the driest condition in wet weather, while exposed freely as regards its outer surface to the cleansing action of rain." This is a concise and correct statement in the main, but we think Mr. Culley overrates the beneficial effect arising from the cleansing of the insulators by exposure to rain. In wet weather the outer surface will conduct, whether clean or otherwise. Of course, a clean surface helps to insulate the line in fine weather, when help is least needed; but if a circuit can be so insulated as to work well in wet weather there will be no trouble at other times. This result may be accomplished simply by prac-

tically carrying out the principles above laid down by Mr. Culley, which has been done to the fullest possible extent in the American paraffined insulator, invented by Brooks. A glass bottle, protected by an iron shield, is interposed between the wire-holder and the support, having a diameter of about an inch, and an insulating length of about 9 inches. This is kept dry in wet weather by the use of paraffine, as well as by its form and arrangement in regard to the pole and wire. Compare this with the ordinary glass insulator, having a diameter of two inches or more, and an insulating length of two inches, and the reason of the superiority of the first is apparent, leaving the paraffine out of the question.

We cordially endorse all that Mr. Culley says in regard to the periodical cleansing of insulators. To keep a telegraph line in thorough working order the insulators ought to be cleaned every year, whatever kind may be used. It seems exceedingly strange that people will build a telegraph line, and expect it to keep itself in order for ever afterwards, unless it actually falls down from decay. If they build a house they expect to paint it every three or four years; if they build a railroad they are continually at work repairing it, but if the insulation of a telegraph line becomes defective from the accumulation of years of dirt and neglect, there is no remedy but to throw all the insulators away and try some other kind, perhaps better, but quite as likely to be worse than the original variety. The pig-headed stupidity of the American telegraphic mind upon this subject would be irresistibly laughable were it not so humiliating.

The chapter on the construction of lines contains a great amount of useful advice; much of which, however, is more valuable to the English than to the American constructor. The latter, however, cannot fail to be benefited by a careful study of European methods, as they abound in valuable hints, which may be practically carried out to advantage in this country, though frequently by entirely different processes.

In the present edition the portion relating to submarine telegraphy has been re-written and enriched by the addition of a very large amount of new matter. The methods employed in testing the French Atlantic cable, during its manufacture and submersion, are very fully described and profusely illustrated, and the student of this interesting but abstruse and difficult branch of electrical science will find in this work his most valuable compendium. It is fully up with the most recent discoveries and investigations.

The work is rather scantily illustrated as a whole, and the cuts and diagrams are not remarkable for their artistic elegance, but otherwise the mechanical execution of the book is worthy of the highest praise. The type, printing, paper and binding, are all of the first quality. We are glad to note the rapidly increasing demand for books of this class, and can assure our readers that they will find this one of the very best of its kind.—*The Telegrapher.*

ANNUAL REPORT OF THE STATE GEOLOGIST OF NEW JERSEY, for 1869. 8vo, 57 pp. and map.

Professor George H. Cook, the State Geologist, gives a valuable report on the economic geology of New Jersey, and enriches it with several carefully drawn maps. It does not cost the State much to carry on such a survey, or to publish its results, while the benefit of disseminating the information is very great. The best way to develop the hidden resources of any country is to bring them out of their hiding places by well conducted geological surveys, and the State that shows the most zeal in this direction will reap the earlier returns of increased emigration.

WINSLOW'S COMPREHENSIVE MATHEMATICS: Being an extensive cabinet of numerical, arithmetical, and mathematical facts, tables, data, formulas, and practical rules for the general business man, merchant, mechanic, accountant, teachers of schools, etc. Eighth edition, revised and enlarged; 380 pp.; $2 50. Boston and New York: E. S. Winslow, 1870. For sale by Van Nostrand.

The tables, showing the values in American currency of the moneys of the different nations of the world, and the great variety of information about weights and measures here collected, make this book a valuable addition to the list of school text-books, as well as a convenient manual for the business man. Some of the more recent problems which have arisen in natural philosophy and chemical science are also taken up and treated in a way which may be easily understood by beginners.

NATHAN READ. HIS INVENTION OF THE MULTI-TUBULAR BOILER AND PORTABLE HIGH-PRESSURE ENGINE, AND DISCOVERY OF THE TRUE MODE OF APPLYING STEAM-POWER TO NAVIGATION AND RAILWAYS. By his friend and nephew, DAVID READ. New York: Hurd & Houghton. For sale by Van Nostrand.

This is an exceedingly interesting addition to the history of the application of the steam-engine to locomotion. Neither the steamboat nor the locomotive was successful until after the invention of the multi-tubular boiler. Mr. Read's claim to the original invention of this important adjunct to Watt's engines, is well set forth by the letters and sketches made as early as 1789.

The volume is a handsome book of 200 pages, illustrated by several wood-cuts.

ICE. A LECTURE DELIVERED BEFORE THE KESWICK LITERARY SOCIETY, and published by request; to which is appended a GEOLOGICAL DREAM OF SKIDDAW. By J. CLIFTON WARD, F. G. S. London: Trubner & Co. For sale by Van Nostrand.

The subjects treated in the lecture are:

1. Some of the physical properties of ice.
2. Ice considered as a natural agent.
3. The marks of ice action in the lake district of Cumberland pointing to a former condition of things, different from that now prevailing.

MEMOIRE SUR LE TELOMETRE A PRISMES. Par G. M. GOULIER. Paris. Libraire Militaire. For sale by Van Nostrand. The instrument described in this *mémoire* is a convenient addition to the outfit of military engineers, and might be made serviceable in the hands of civil engineers when conducting reconnoissances.

ELEMENTARY PRINCIPLES OF CARPENTRY.—A Treatise on the equilibrum of timber framing, the resistance of timber, and the construction of floors, centres, bridges, roofs, etc., etc. To which

is added an essay on the nature and properties of timber, etc. By THOMAS TREDGOLD. Fifth edition, corrected and considerably enlarged, with an appendix containing specimens of various ancient and modern roofs, by PETER BARLOW, F. R. S. London: Lockwood & Co. For sale by Van Nostrand.

There are but few names so familiar to students of the science of building as Tredgold. Its value to the practical architect is sufficiently attested by the demand which has called forth this new edition.

The number of plates has been increased over those of the former editions, by the illustration of some modern examples.

MEMOIRE SUR LE POINT OBSERVE ET LA DETERMINATION DES COURANTS A LA SURFACE DES MERS. Par A. FASCI, Professor d'Hydrographie. For sale by Van Nostrand.

This book of sixty pages is a good supplement to the better works on navigation. The first part is purely theoretic and abounds in mathematical formulas. The second part consists of practical problems worked out in illustrations of the formulas. Five folding plates, containing thirteen figures, illustrate the text.

A TREATISE ON MEDICAL ELECTRICITY, Theoretical and Practical, and its use in the Treatment of Paralysis, Neuralgia, and other diseases. By JULIUS ALTHAUS, M. D. London: Longmans, Green & Co. For sale by Van Nostrand.

This volume of 700 pages is divided into five chapters, which treat respectively upon: Forms of electricity; electro-physiology; medical electric apparatus and methods of applying electricity; electricity as a means of diagnosis, and electro-therapeutics.

The work is designed for the practising physician, and abounds in *cases* treated by the methods prescribed by the author.

NAUTICAL ASTRONOMY AND NAVIGATION. By H. W. JEANS, F. R. A. S. London: Longmans, Green, Reader and Dyer. For sale by Van Nostrand.

Part one, containing rules for finding the latitude and longitude, and the variation of the compass, with numerous examples. Part two, containing the investigations and proofs of the principal rules and corrections, with practical examples.

A TOPOGRAPHICAL MAP OF TREASURE HILL, White Pine County, Nevada. Compiled from actual survey by subscription of the principal mining companies and capitalists of the district. By WM. HAMMOND HALL and EDMUND F. DICKINS. New York: D. Van Nostrand.

CONSTITUTION DE LA MATIERE ET SES MOUVEMENTS. NATURE ET CAUSE DE LA PESANTEUR. Par LE P. LEBAY. Paris: Au Bureau du Journal Des Mondes. For sale by Van Nostrand.

LA LUMIERE ELECTRIQUE APPLIQUEE A LA NAVIGATION. Paris: Libraire Maritime et Scientifique. For sale by Van Nostrand.

MISCELLANEOUS.

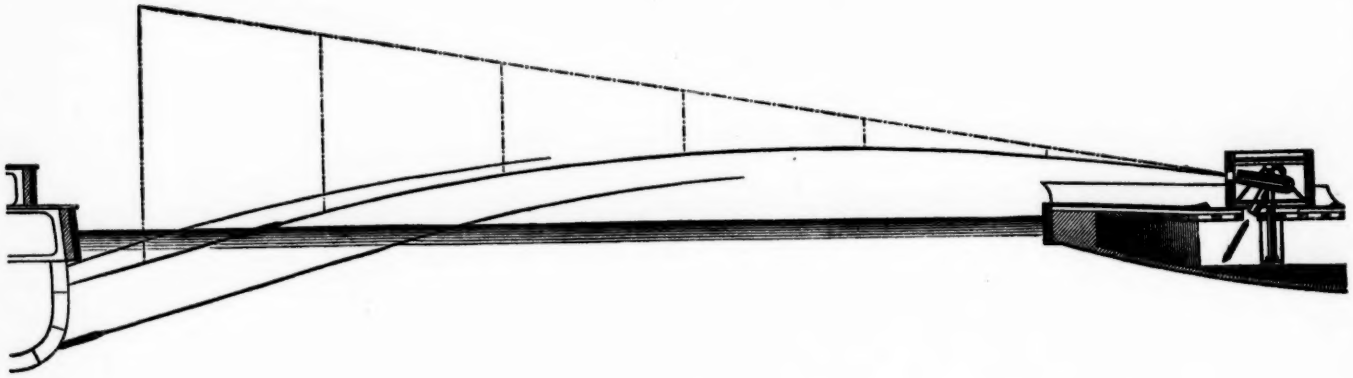
THE VALUE OF INVENTIONS.—In one of the Lowell Institute lectures, lately delivered in Boston, the speaker, General Samuel A. Duncan, made mention of some notable examples of the value to the world of patented improvements, as follows: "The expenses of the Patent Office up to the present time have been $5,583,337.35, to which, if there be added the cost of the building itself, and the money expended upon the annual reports, the entire sum will reach perhaps $12,000,000. But what is this compared to the benefit derived by the public from a single invention of real importance? There are, perhaps, 400,000 sewing-machines in use in the country. Ten cents a day would seem an absurdly low estimate of the value of each of these to its owner; and yet even *this* daily profit would make the aggregate annual sum to the community from this source alone $15,000,000. It is computed that the saving of grain by the use of thrashing-machines in place of the flail, which they have supplanted, is 10,000,000 bushels annually. It is the inevitable tendency of all improvements in the arts to cheapen production. Heathcoat's machines reduced the price of bobbin net lace from five guineas a yard to sixpence. The Bigelow looms for weaving ingrain carpets both reduced the cost of the manufactured article 20 per cent. and improved the quality of the goods. The cotton-gin reduced our price of raw cotton by stimulating the production so that it has increased in three years from 138,000 lbs. to 5,000,000 lbs."

MR. J. N. DOUGLASS recently read a paper on the Wolf Rock Lighthouse, before the Institution of Civil Engineers. He said that, when it was resolved to fit up for that lighthouse a revolving dioptric light, showing alternate flashes of red and white at half-minute intervals, the arrangement involved the consideration of the question of disposing in each beam the relative proportion of light to allow for the loss in red beams by passing through a ruby glass medium. The investigation of the subject was entered into by Professor Tyndall, the scientific adviser of the Trinity House; and as it was one which could not be determined with accuracy by photometric measurements, he, with the author, paid a visit to the Rock Lighthouse, near Liverpool, which had a catoptric revolving light showing one red flash succeeded by two of white at intervals of one minute, and inquiries and observations were made on this light at the Point of Air Lighthouse, at a distance of 11¼ miles, and at the Great Ormes Head Lighthouse, at a distance of 30½ miles. Experiments with red and white lights were also made in the experimental lighthouse of the Trinity House at Blackwall, and observations on these were taken from a station in Charlton, at a distance of two miles. From these practical tests it was determined that the quantity of light to be appropriated to the red beam should be to that of the white in the ratio of 5275 to 2250, or as 21 to 9 nearly.

TREES IN CITIES.—Dr. Poselger has proven by experiments that the death of fine trees in cities is not due to the leakage of gas mains, as has often been asserted; and that no damage can accrue to the trees, nor their growth be interfered with, by any quantity of gas which may escape in the soil and find its way to their roots.—*Quarter'y Journal of Science.*

CAPTAIN ERICSSON'S NEW SYSTEM OF SUBMARINE ATTACK.

SEE PAGE 635.



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